This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at http://books.google.com/

SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
FIAT LVX
MDCCCLXVIII
EX LIBRIS

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

THE PITTSBURGH REDUCTION CO.

MANUFACTURERS OF

ALUMINUM

UNDER THE PATENTS OF CHARLES M. HALL.

ALUMINUM AND ALUMINUM ALLOYS

IN THE FORM OF

INGOTS, CASTINGS, BARS, PLATES, SHEETS, TUBES, WIRE, AND ALL FORMS OF STRUCTURAL SHAPES.

MAIL ADDRESS: - -	- PITTSBURGH, PA., U. S. A.
TELEGRAPH ADDRESS, -	- NEW KENSINGTON, PA.
CABLE ADDRESS, - -	- REDUCTION—NEWKENSINGTON.

USE A I CODE, A. B. C. CODE (FOURTH EDITION), OR LIEBER'S CODE.

PITTSBURGH, PA., U. S. A.

1904.

FIFTH EDITION.

EWENS & EBERLE, BOOK AND JOB PRINTERS, 208 AND 210 THIRD AVENUE, PITTSBURGH, PA.

Digitized by Google

TN775
P5
1904

ALUMINUM
T.P.R.Co.

TRADE MARK.

COPYRIGHTED 1897

BY THE PITTSBURGH REDUCTION CO.

UNIV. OF
CALIFORNIA

Digitized by Google

8

CONTENTS.

PART I.

DATA WITH REFERENCE TO ALUMINUM.

193385

Digitized by Google

METHODS OF WORKING ALUMINUM.

GENERAL REMARKS UPON ALLOYS.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Aluminum

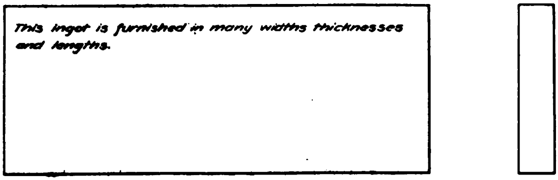
The

Pittsburgh Reduction

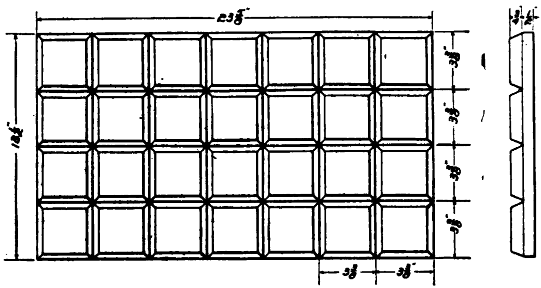
Company

Digitized by Google

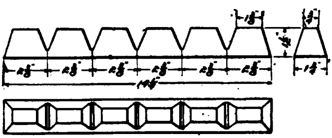
DIMENSIONS OF INGOTS FURNISHED BY THE PITTSBURG REDUCTION CO.



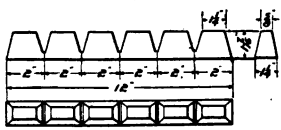
ROLLING INGOT.



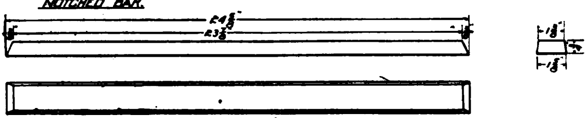
WAFFLE INGOT.



NOTCHED BAR.

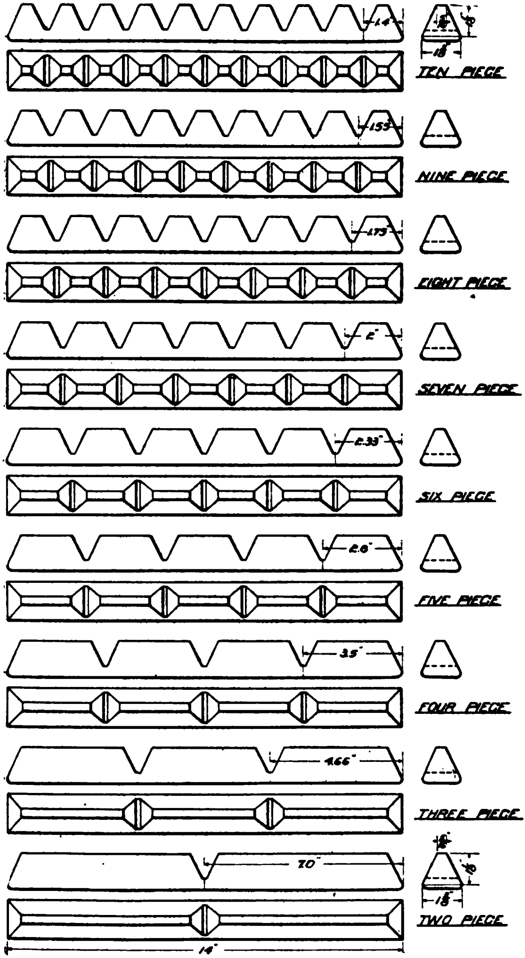


SMALL NOTCHED BAR.



STRAP INGOT.

Digitized by Google



STANDARD INGOTS

Digitized by Google

COMPILED BY ALFRED E. HUNT, S. B.

PRICE, $1.50.

ACKNOWLEDGMENTS:

REFERENCES HAVE BEEN MADE AND EXTRACTS TAKEN BY PERMISSION FROM THE FOLLOWING AUTHORITIES:

"Pocket Companion," of the Carnegie Steel Co., Ltd., edited by F. H. Kindl, C. E.

"Mechanical Engineers' Reference Book," by Nelson Foley, published by Crosby, Lockwood & Co., 7 Stationers Hall, London.

"A Dictionary of Metric and other Useful Measures," by Latimer Clark, published by E. & F. N. Spon, 25 Strand, London.

"Alloys for Brasses and Bronzes," by Prof. R. H. Thurston, Cornell University, Ithaca, N. Y.

"Introduction to the Study of Metallurgy," by Sir W. C. Roberts-Austen, published by Chas. Griffin & Co., London.

"Gauges at a Glance," by Thomas Taylor, published by Dunsford & Son, South Castle Street, Liverpool, England.

"Monetary Systems of the World," M. L. Muhleman, Deputy Assistant Treasurer of the United States.

"Mechanical Engineers' Pocket Book," by Wm. Kent, C. E., published by John Wiley and Sons, New York.

"Mechanics & Engineers' Pocket Book," by Chas. H. Haswell, published by Harper & Bro., New York.

"Chemical Technology," Groves & Thorp, "Fuels," published by P. Blakiston, Son & Co., Philadelphia.

Digitized by Google

ALUMINUM.

The aluminum manufactured by The Pittsburgh Reduction Company is guaranteed to be equal in purity to the best metal in the market.

The metal is very ductile, and has frequently been subjected to the most severe tests with most satisfactory results. It can be rolled into sheets of .0007″ thickness, and from this beaten into leaf, equal in quality to the best leaf manufactured in the world. It can also be drawn into tubes or wire and spun or stamped into different shapes. It is susceptible of a high degree of finish by polishing or burnishing. Aluminum like other metals becomes hard by working, but requires less annealing than copper or brass, but if required soft, as for stamping or spinning, it must be annealed after rolling. By forging and cold rolling it can be given considerable rigidity and temper.

The rigidity and temper of aluminum is considerably increased by the addition of a few per cent. of hardening ingredients. The metals commonly used for this purpose are nickel, copper, chromium, tungsten, manganese, tin, iron and zinc.

In plates and sheets these metals are added in amounts not to exceed five or six per cent., for greater percentages render these aluminum alloys non-malleable.

Digitized by Google

The Pittsburgh Reduction Company sell hard plates, sheets and sections of tensile strength superior to that of brass under the trade name of "NICKEL ALUMINUM;" these "NICKEL ALUMINUM plates, sheets and sections having a composition of from two to five per cent. of nickel and copper, alloyed with pure aluminum, and with a specific gravity of about 2.75, are furnished either hot rolled and annealed for stamping and spinning, or medium hard rolled, or cold rolled and very stiff, as may be required. The same ingredients, nickel and copper, added in proportions of from seven to ten per cent., form the "NICKEL ALUMINUM CASTING ALLOYS," which are sold by The Pittsburgh Reduction Company for cast hollow ware and other castings, where some malleability together with great ductility and toughness are required.

This metal is easy to cast in either iron or sand moulds, has about the same shrinkage as brass, and has a specific gravity of from 2.80 to 2.85. The Pittsburgh Reduction Company sell under the name of "SPECIAL CASTING ALLOY," a metal containing over eighty per cent. of pure aluminum alloyed with zinc, copper, tin, manganese and iron, having a specific gravity of about 3.0. This alloy has a tensile strength about equal to that of brass, has no more shrinkage than brass, and can be as easily tooled or cast. If this "SPECIAL CASTING ALLOY" is found too brittle for any particular use, it can be toughened by re-melting and adding pure aluminum.

Special attention is given in the fabrication of aluminum alloys, by The Pittsburgh Reduction Company, to avoid oxidation, and to this end rich alloys are first made, to be afterwards reduced down to their proper percentages by re-melting with pure aluminum. These rich alloys are made in the electrical pots or furnaces at the same time that the aluminum is made, in this way more perfectly combining the metals than can possibly be done by melting them and mixing in crucibles where their varying melting points render the oxidation from over-heating very liable to occur.

Aluminum is the lightest of the commercial metals. A given bulk of it being only one-third as heavy as a corresponding bulk of iron.

Digitized by Google

COMPOSITION AND FORMS OF THE ALUMINUM AS SOLD BY THE PITTSBURGH REDUCTION CO.

The purity of commercial aluminum varies from 98% to 99.75%. The Pittsburgh Reduction Co. sells its commercial aluminum in three grades.

THE No. 1 GRADE of aluminum has an analysis approximately as follows:

Silicon,	0.30%.
Iron,	0.15%.
Aluminum,	99.55%.

EXTRA PURE ALUMINUM. The Pittsburgh Reduction Company always have in stock, however, metal still purer than this, some running as high as 99.90% pure, which is sold for special uses at an added price.

THE No. 2 GRADE ordinarily runs quite uniform in composition, and has an analysis approximately as follows:

Silicon,	2%.
Iron,	2%.
Aluminum,	96%.

This metal, however, is not guaranteed to be over 94% pure.

There can occasionally be bought aluminum ingots made from scrap. It is evident, however, that if scrap ingots are made from aluminum or alloyed aluminum, whose composition is unknown to the makers of such ingots, that great risk is run of unknowingly using aluminum unfitted for the purpose.

For instance, for the steel trade, aluminum scrap ingots containing copper, nickel, zinc and tin, are manifestly injurious, while such scrap ingots might be safely used, if their composition is known, by brass manufacturers; and, on the other hand, aluminum having considerable silicon and iron in its composition which might answer satisfactorily to the steel maker, would be injurious to brass.

ROLLING INGOTS. Sound ingots of the No. 1 grade metal, suitable for rolling, are kept in stock of which the following are some of the sizes:

Digitized by Google

ROLLING INGOTS.

12 inches	x 3 inches	x 18 inches.
7 "	x 3 "	x 22 "
12 "	x 1⅜ "	x 18 "
12 "	x 1⅛ "	x 18 "
11½ "	x 1 "	x 16 "
10 "	x 1 "	x 18 "
8 "	x ⅞ "	x 18 "
6 "	x ¾ "	x 12 "
2 "	x ½ "	x 5½ "
4 "	x 2 "	x 84 "
3½ "	x 3½ "	x 36 "
2½ "	x 2½ "	x 36 "

Ingots of any size can be furnished, providing the amount of metal ordered will warrant the expenditure for moulds.

ROLLING SLABS Which have been "broken down" from thick ingots and rolled to about ⅜ of an inch in thickness, free from flaws and with sound rolled edges and ends sheared off square, are furnished of any desired widths by The Pittsburgh Reduction Company.

The purchase of the metal in this form, reduces to a minimum the amount of scrap produced, and ensures for the manufacturer of the finished sheet a perfect and sound stock

Metal furnished in this form has become deservedly popular with manufacturers possessing rolling mills.

ALUMINUM INGOTS FOR RE-MELTING Are kept in stock of the various grades of metal, in what are called "waffle" ingots. They are square placques, three inches on a side and of about ¾ of an inch in thickness and weigh about one-half pound each; they are connected together by thin webs, which makes them easily detachable from an ingot four "waffles" wide by seven long, weighing about fourteen pounds.

The Pittsburgh Reduction Company also furnish aluminum for re-melting, in ingots 14 inches long and 1¼ inches wide, which ingots are so notched as to be easily divided into small pieces. These ingots are made with different number of notches as shown in the sketch on the second

Digitized by Google

page of this catalogue. Thus, ingots of the above length and width can be furnished to be broken up in any number of pieces from two to ten. For convenience sake The Pittsburgh Reduction Company use for each of the several grades of metal a certain one of the above forms, although if so desired, metal of the different grades will be furnished in any of these ingots.

ALUMINUM BRONZE POWDER. "Bronze" is the name technically given in the trade to metallic powders, and ALUMINUM BRONZE POWDERS consist of finely powdered pure aluminum. They are prepared by beating out, under trip hammers, thin rolled sheets of aluminum into very thin foil; this foil is afterwards ground into powder in especially designed grinding mills.

Aluminum Bronze Powder is only made from the purest and best grades of aluminum, for only this quality of aluminum is malleable enough to permit of its being hammered into sufficiently thin foil for the purpose. Aluminum Bronze Powders are, however, sometimes adulterated with Tin Bronze Powders.

Aluminum Bronze Powder is largely used as a metallic paint, it having almost entirely replaced the previous use of silver for this purpose. It is also largely used in the manufacture of wall paper, and for a coloring matter in the manufacture of celluloid and rubber materials.

MIN KAPH LIBRARY
CHEM. BLDG. U. C

DATA ON VARNISH FOR ALUMINUM BRONZE.

The liquid which is sold in the United States under the trade name of the "Light Japan Gold Size," is the best varnish to use with powdered "Aluminum Bronze," This, however, is not the same article as is sold in England under the name of the "Gold Size," and the best of these varnishes is made by taking fifty pounds of Kauri and fifty pounds of Zanzibar resin, together with five gallons of refined linseed oil, cooking these at a high temperature until there is no free oil left. This mixture should then be "thinned down" with a proper amount of turpentine, (about twenty-five or thirty gallons) and then a "drier" should be added.

Digitized by Google

PROPERTIES OF ALUMINUM.

Including Data Regarding Some of the Properties of Other Metals for Reference.

SOLUBILITY. Hydrochloric acid is the natural solvent for aluminum. Dilute sulphuric acid slowly dissolves the metal on heating.

Concentrated sulphuric acid acts only very slowly on the metal, although the sulphuric acid of commerce usually contains an amount of hydrochloric acid sufficient to rapidly act on the metal.

Nitric acid, either concentrated or dilute, has very little action on aluminum when cold; when heated it acts very slowly.

Sulphur has no action at a temperature less than a red heat. Solutions of caustic alkalies, chlorine, bromine, iodine and fluorhydric acid rapidly corrode the metal.

Aluminum is found to withstand the action of organic secretions better than silver, and is receiving large use for dental plates and surgical instruments, and in places where subjected to carbolic acid or other antiseptic solutions.

Aluminum is little acted upon by salt water. Solutions of salt and vinegar such as it is apt to be subjected to in ordinary culinary operations, do not injure the metal.

Aluminum is little acted upon by mineral waters, and withstands the action of sea water better than iron, steel or copper. Strips of aluminum placed upon the sides of a wooden vessel corroded less than $\frac{5}{1000}$ths of an inch after six months exposure to sea water. Copper sheet treated similarly was cor-

Digitized by Google

roded to nearly double this amount. In salt water barnacles will attach themselves to unprotected aluminum vessels, but these can be protected with special paints or varnishes. Aluminum has been successfully used for structural purposes under water and is standing such exposure much better than steel, wrought iron, or even cast iron. It has been used as shims in masonry foundations, and lasts well in such places. It has also been used to a small extent for roofing, and doubtless this use will be extended as its advantages become better known, more especially as aluminum is now relatively cheaper than copper.

Ammonium solutions gradually attack the surface of aluminum leaving behind a more resisting surface coating containing silicon, which, although rapidly attacked by concentrated alkali or acid solutions resists corrosion from dilute mineral acids and dilute solutions of organic acids as well as moist or dry air. An aluminum surface thus treated has a brown color which may be given different shades; it may be left smooth or with a rough finish, or matt, and is really a very serviceable way to treat the metal for a durable finish to withstand corrosion.

Aluminum is not acted upon by carbonic acid, carbonic oxide, or sulphuretted hydrogen; but on being melted, will absorb these gases, quite a portion of which is again excluded on the metal cooling.

The presence of the impurities silicon and sodium in aluminum markedly decrease the power of the metal to resist corrosion, and most of the failures from this cause are due to these impurities.

The occlusion of gases in molten aluminum, such as nitrogen, carburetted hydrogen, etc., occasion blow-holes in the ingots, which in turn make laminated plates when the ingots are afterward rolled or hammered. Such laminated material is much more liable to corrosion than is sound metal.

GALVANIC ACTION. The common metals are very electro-negative to aluminum in a voltaic couple, and as the electro-positive element is the one attacked first and most severely,

Digitized by Google

and the electro-motive force (or force produced by the difference in chemical action between aluminum and any of the common metals with which it comes in contact in a voltaic element), is equal to the sum of the electro-motive forces between all the intervening metals, it follows that care should be taken that aluminum exposed to water or other solutions shall not come in contact with any other metal, which will cause a voltaic couple to be formed.

Aluminum can be protected in places where it is exposed to galvanic action, by insulating with rubber, or canton flannel soaked in a mixture of white lead and oil, or some other non-conducting substance. It can also be protected by placing between the aluminum and the metal with which it is in contact, a more electro-positive metal, such as magnesium, where the metal from which the aluminum is insulated is electro-negative to it, as is the case with most metals.

The table given below shows what metals are electro-positive or electro-negative to each other :

POSITION IN ELECTRO-CHEMICAL SERIES.

IN THE ORDER OF THE MOST POSITIVE FIRST:

1	Caesium,	17	Nickel,	33	Rhodium,
2	Rubidium,	18	Thallium,	34	Platinum,
3	Potassium,	19	Indium,	35	Osmium,
4	Sodium,	20	Lead,	36	Silicon,
5	Lithium,	21	Cadmium,	37	Carbon,
6	Barium,	22	Tin,	38	Boron,
7	Strontium,	23	Bismuth,	39	Nitrogen,
8	Calcium,	24	Copper,	40	Arsenic,
9	Magnesium,	25	Hydrogen,	41	Selenium,
10	**Aluminum,**	26	Mercury,	42	Phosphorus,
11	Chromium,	27	Silver,	43	Sulphur,
12	Manganese,	28	Antimony,	44	Iodine,
13	Zinc,	29	Tellurium,	45	Bromine,
14	Gallium,	30	Palladium,	46	Chlorine,
15	Iron,	31	Gold,	47	Oxygen,
16	Cobalt,	32	Iridium,	48	Fluorine.

Authority "Electrolytic Separation of Metals," (1890.)—By G. Gore, F. R. S.

Digitized by Google

MELTING POINT. Aluminum melts at a temperature between silver and zinc—a temperature of about 650 degrees Centigrade, or 1,200 Fahrenheit (according to the latest experiments.) It has been found that a small percentage of iron materially raises the melting point. Aluminum does not volatilize at any temperature ordinarily produced by the combustion of carbon, even though the high temperature be kept up for a considerable number of hours. It, however, is not good practice in making castings of aluminum to heat it much above its melting point, or to allow it to remain melted for any great length of time, on account of its capacity for absorbing gases.

MELTING POINTS OF VARIOUS SUBSTANCES.

The following figures are given by Clark (on the authority of Pouillet, Claudel & Wilson), except those marked (*), which are given by Prof. Roberts-Austen. The latter are probably the most reliable figures:

	Deg. Cent.	Deg. Fahr.
Sulphurous Acid	−100	−148
Carbonic Acid	−77.8	−108
Mercury	−39.4	−39
Bromine	−12.6	9.5
Turpentine	−10	14
Hyponitric Acid	−8.9	16
Ice	0.0	32
Nitro-Glycerine	7.2	45
Tallow	33.3	92
Phosphorus	44.4	112
Acetic Acid	45.0	113
Stearine	42.8 to 48.9	109 to 120
Spermaceti	48.9	120
Margaric Acid	55.0 to 60.0	131 to 140
Potassium	57.8 to 62.2	136 to 144
Wax	61.1 to 67.8	142 to 154
Stearic Acid	70.0	158
Sodium	90.0 to 97.8	194 to 208
Alloy, 3 lead, 2 tin, 5 bismuth,	92.8	199

Digitized by Google

MELTING POINTS OF VARIOUS SUBSTANCES.—Continued.

	Deg. Cent.	Deg. Fahr.
Iodine	107.2	225
Sulphur	115.0	239
Alloy, 1½ tin, 1 lead	167.8	334
Alloy, 1 tin, 1 lead	187.8 to 240.1	370 to 466
Tin	227.8 to 230.0	442 to 446
Cadmium	227.8	442
Bismuth	262.2 to 263.9	504 to 507
Lead	325.6*	618*
Zinc	415.0*	779*
Antimony	432.2 to 621.1	810 to 1150
Aluminum	**625.0***	**1157**
Magnesium	648.9	1200
Calcium		Full red heat.
Bronze	922.2	1692
Silver	945.0*	1733*
Potassium Sulphate	1015.0*	1859*
Gold	1045.0*	1913*
Copper	1053.9*	1929*
Cast Iron, White	1050.0 to 1135.0*	1922 to 2075*
Cast Iron, Gray	1220.0* to 1530.0	2228* to 2786
Steel	1300.0 to 1377.8	2372 to 2532
Steel, Hard	1410.0*	2570*
Steel, Mild	1475.0*	2687*
Wrought Iron	1500.0 to 1600.0	2732 to 2912*
Palladium	1500.0*	2732*
Platinum	1775.0*	3227*

The melting point of metals varies in the tables given by standard authorities due to amount of impurities contained in the samples experimented upon, and also due to the slight inaccuracy of the instruments or methods used in determining high temperatures, as well as to errors in observation.

A table showing results of various observations on the melting points of some of the metals, is given below, to illustrate the discrepancy between the various authorities ; it also gives further information for interpreting the average and approximate results of melting point tables in this pamphlet :

Digitized by Google

METAL.	MELTING POINT.	OBSERVER.
Antimony......	450................	Watts.
"	432................	Dalton.
"	425	Fehling.
"	440................	Pictet, 1879.
" Comm'l	432........	Ledebur, 1881.
Lead	322................	Daniell, 1830.
"	326................	Rudberg, 1848.
"	325................	Vincentini & Omodei, 1888.
"	326................	Ledebur, 1881.
"	326, by air therms. & 334, by merc'y therm.	Persons.
"	335................	Pictet, 1879.
Iridium........	2200..............	V. A. Weyde.
"	1950, Calor........	Violle, 1873.
Copper........	1090..............	Daniell, 1830.
"	1000-1200....	Pouillet, 1836.
"	1236.............	Wilson, 1852.
"	1050.........	Pictet, 1879.
" Comm'l.	1100.............	Ledebur, 1881.
"	1054..............	Violle, 1879.
Gold	1100	Pictet, 1879.
"	1035, Calor........	Violle, 1879.
"	1144.....	Daniell, 1830.
"	1200..............	Pouillet, 1836.
"	1250..............	V. A. Weyde.
"	1240..............	Pictet, 1879.
Nickel........	1450..............	Carnelli & Carleton Williams.
"	1450..............	Pictet, 1879.
"	1392-1420.........	Schertel, 1880.
Palladium......	1360-1380.........	Becquerel, 1862.
"	1950........	Carnelli, 1879.
"	1700..............	Pictet, 1879.
"	1500, Calcr........	Violle, 1879.
Platinum..	1460-1480........	Becquerel, 1863.
"	1779..............	Violle, 1879.

Digitized by Google

METAL.	MELTING POINT.	OBSERVER.
Platinum.......	2200.................	V. A. Weyde.
"	2000.................	Pictet, 1879.
Zinc...........	412.................	Daniell, 1830.
"	433 by merc. thermo.	
"	415 by air thermo....	Persons, 1848.

The above observations have been made with mercury thermometers as far as possible, the higher temperature with the air thermometer; except where stated Violle has used the calorimeter. The temperatures have not necessarily been made by the above observers, but have in some instances been taken from their works.

The Centigrade scale was used throughout.

The following table of physical properties of metals, published by a well known authority, is appended, as giving further determinations of the melting points of metals:

Digitized by Google

PHYSICAL PROPERTIES OF METALS.

FROM "AN INTRODUCTION TO METALLURGY," BY PROF. W. C. ROBERTS-AUSTEN, C.B., F.R.S.,
Associate of the Royal School of Mines, Chemist and Assayer of the Royal Mint.

	Symbol.	Atomic Weight.	Atomic Volume.	Specific Gravity.	Specific Heat.	Melting Point.	Co-efficient of Linear Expansion.	Thermal Conductivity.	Electrical Conductivity.
						C.		Ag.=100.	Hg.at 0°=1
Aluminum,	**Al.**	**27.00**	**10.6**	**2.56**	**0.2120† 0.2185***	**625† 654***	**0.0000231**	**31.33**	**35.29**
Antimony	Sb.	120.00	17.9	6.71	0.051	440† 630*	0.0000105	4.03	2.053
Arsenic	As.	74.90	13.2	5.67	0.081	—	0.0000055	—	2.679
Barium	Ba.	136.86	36.5	3.75	0.047	1200			
Bismuth	Bi.	207.50	21.1	9.80	0.031	268	0.0000162	1.8	0.800
Cadmium	Cd.	111.70	12.9	8.60	0.057	320	0.0000306	20.06	13.95
Cæsium	Cs.	132.70	70.6	1.88	—	26			
Calcium	Ca.	39.91	25.4	1.57	0.170	Red heat.	—	—	12.46
Cerium	Ce.	141.00	21.0	6.68	0.045	Between Sb. & Ag.			
Chromium	Cr.	52.40	7.7	6.80	(0.120)	higher than Pt.			
Cobalt	Co.	58.60	6.9	8.50	0.110	1500	0.0000123	—	9.685
Copper	Cu.	63.20	7.2	8.82	0.094	1080* 1050†	0.0000167	73.6	55.86
Didymium	Di.	145.00	22.3	6.54	0.046				
Glucinum	Gl.	9.08	5.6	2.07	0.580				
Gold	Au.	196.20	10.2	19.32	0.032	1045† 1062*	0.0000144	53.2	43.84
Indium	In.	113.40	15.3	7.42	0.057	176	0.0000417		
Iridium	Ir.	192.50	8.6	22.42	0.033	2500	0.0000070		
Iron	Fe.	55.90	7.2	7.86	0.110	1600	0.0000121	11.9	8.341
Lanthanum	La.	138.50	22.3	6.20	0.045				
Lead	Pb.	206.40	18.1	11.37	0.031	325	0.0000292	8.5	4.818
Lithium	Li.	7.01	11.9	0.59	0.941	180	—	—	10.69

‡ Authority—Landolt and Bornstein. † Roberts-Austen. * Haycock and Neville.

Digitized by Google

PHYSICAL PROPERTIES OF METALS.—Continued.

	Symbol.	Atomic Weight.	Atomic Volume.	Specific Gravity.	Specific Heat.	Melting Point.	Co-efficient of Linear Expansion.	Thermal Con-ductivity.	Electrical Con-ductivity.
						C.		Ag.=100.	Hg.at 0°=1
Magnesium	Mg.	23.94	13.8	1.74	0.250	750† / 633*	0.0000269	34.3	22.57
Manganese	Mn.	54.80	6.9	8.00	0.120	1900			
Mercury	Hg.	199.80	14.7	13.59	0.032	—39	—	1.3	1.000
Molybdenum	Mo.	95.90	11.1	8.60	0.072				
Nickel	Ni.	58.60	6.7	8.80	0.110	1600	0.0000127	—	7.374
Niobium	Nb.	94.00	15.0	6.27	?				
Osmium	Os.	195.00	8.7	22.48	0.031	2500	0.0000065		
Palladium	Pd.	106.20	9.2	11.50	0.059	1500	0.0000117	—	6.910
Platinum	Pt.	194.30	9.1	21.50	0.033	1775	0.0000089	8.4	8.257
Potassium	K.	39.03	45.4	0.87	0.170	62	0.0000841	—	11.23
Rhodium	Rh.	104.10	8.6	12.10	0.058	2000	0.0000085		
Rubidium	Rb.	85.20	56.1	1.52	0.077	38			
Ruthenium	Ru.	103.50	8.4	12.26	0.061	1800	0.0000096		
Silver	Ag.	107.66	10.2	10.53	0.056	945† / 961*	0.0000192	100.0	57.226
Sodium	Na.	22.99	23.7	0.97	0.290	95	0.0000710	36.5	18.30
Strontium	Sr.	87.20	34.9	2.54	0.074	—	—	—	3.774
Tantalum	Ta.	182.00	16.9	10.80	?				
Tellurium	Te.	126.30	20.2	6.25	0.047	525	0.0000167	—	0.0004
Thallium	Tl.	203.70	17.1	11.85	0.034	288	0.0000302	—	5.225
Thorium	Th.	232.00	20.9	11.10	0.028				
Tin	Sn.	117.40	16.1	7.29	0.056	227† / 232*	0.0000223	15.2	8.237
Titanium	Ti.	48.00	—	—	0.130?				
Tungsten	W.	184.00	9.6	19.10	0.033	higher than Mn			
Uranium	U.	240.00	12.8	18.70	9.028				
Vanadium	V.	51.10	9.3	5.50	?	1775			
Zinc	Zn.	64.90	9.1	7.15	0.094	415† / 420*	0.0000291	28.1	16.92
Zirconium	Zr.	90.40	21.7	4.15	0.066				

† Roberts-Austen. * Haycock and Neville.

Probably the most reliable data as to melting points is published by Prof. S. W. Holman in conjunction with R. R. Lawrence and L. Barr, in the "Proceedings of the American Academy," Nov. 13, 1895.

Aluminum,	melting	point,	660	degrees	centigrade.
Silver,....	"	"	970	"	"
Gold,.....	"	"	1072	"	"
Copper,...	"	"	1095	"	"
Platinum, .	"	"	1760	"	"

The aluminum experimented upon was furnished by The Pittsburgh Reduction Co., and contained 99.93 per cent. aluminum, with .07 per cent. silicon.

The silver, gold, copper and platinum were of the purest quality obtainable, probably with less than three one-hundredths of one per cent. of impurity in each case.

LATENT HEAT OF FUSION.

AUTHORITY M. PIERSON.

	Calories. Kilos.	Heat Units. Lbs.		Calories. Kilos.	Heat Units. Lbs.
Mercury.....	2.83	5.1	Silver.......	21.07	38.0
Lead.	5.37	9.7	Zinc.........	28.13	50.7
Bismuth.....	12.64	22.8	***Aluminum..**	**28.50**	**51.4**
Cadmium....	13.66	24.6	*Richards publis's his own results as	**29.00**	**53.00**
Tin.........	14.25	25.7	Water.......	79.00	142.2

The mean SPECIFIC HEAT of aluminum from zero to the melting point is very high, being 0.2185, water being taken as 1, and the latent heat of fusion is 28.5 calories per kilogramme or 51.4 heat units per lb.; that is, the number of heat units required to melt a pound of aluminum, is the same as would raise 51.4 pounds of water through one degree Fahrenheit.

Digitized by Google

THE FOLLOWING IS A TABLE OF COMPARATIVE SPECIFIC HEATS:

SIR ROBERTS-AUSTEN AUTHORITY, EXCEPT WHERE OTHERWISE INDICATED.

Water	1.0000	Nickel	.1100	Antimony	.0510
Lithium	.9410	Copper	.0940	Barium	.0470
Glucinum	.5800	Zinc	.0940	Tellurium	.0470
Sodium	.2900	*Brass, {70 Cu. 30 Zn.}	.0939	Didymium	.0460
Magnesium	.2500			Cerium	.0450
***Aluminum**	**.2185**	Arsenic	.0810	Lanthanum	.0450
Silicon	.1730	Rubidium	.0770	Thallium	.0340
Calcium	.1700	Strontium	.0740	Platinum	.0330
Potassium	.1700	Molybdenum	.0720	Tungsten	.0330
Titanium	.1300?	Zirconium	.0660	Gold	.0320
*Grey Iron	.1268	Ruthenium	.0610	Mercury	.0320
Chromium	.1200	Palladium	.0590	Lead	.0310
Manganese	.1200	Rhodium	.0580	Osmium	.0310
*Steel	.1175	Cadmium	.0570	Bismuth	.0310
*Wr'ght Iron	.1138	Indium	.0570	Thorium	.0280
Pure Iron	.1100	Tin	.0560	Uranium	.0280
Cobalt	.1100	Silver	.0560		

Roberts-Austen gives specific heat of aluminum as 0.2120.
* These values are given on the authority of Landolt & Bornstein.

The specific heat of aluminum being .2185, means that the quantity of heat which would raise the temperature of any given quantity of aluminum through one degree would only raise the temperature of the same quantity of water through .2185 of one degree.

Aluminum follows the general law of specific heats, i. e. that they are inversely as their atomic weights.

Digitized by Google

The following table exhibits the relationship between the combining numbers and specific heats of the metals; the product of specific heat and of the combining number is seen to be very nearly constant, as shown by Kopp. He also verifies the law of Woestyn and Garnier, finding the specific heat of the molecule equal to the sum of the specific heats of the constituent atoms:

SPECIFIC HEATS AND COMBINING NUMBERS.

METALS.	COMBINING NUMBERS.	SPECIFIC HEAT (REGNAULT.)	PRODUCT.
Aluminum,	**27**	**0.2143**	**5.8**
Antimony	122	0.0508	6.1
Arsenic	75	0.0814	6.1
Bismuth.	210	0.0308	6.5
Cadmium	112	0.0567	6.3
Copper	63.5	0.0951	6.0
Gold	196	0.0324	6.4
Lead	207	0.0314	6.4
Iron	56	0.1138	6.1
Magnesium	24	0.2499	6.0
Manganese	55	0.1217	6.7
Mercury (solid)	200	0.325	6.5
Nickel	59	0.1089	6.4
Palladium	106	0.0593	6.3
Platinum	197.6	0.0329	6.5
Potassium	39.1	0.1695	6.5
Silver	108	0.0570	6.2
Sodium	23	0.2934	6.7
Tin	118	0.0562	6.6
Zinc	65	0.0956	6.2

Digitized by Google

SPECIFIC HEATS OF METALS.

	SPECIFIC HEAT.	AUTHORITY.
Wrought iron	.1138	Regnault.
" 32—212 F.	.1098	Dulong & Petit.
" 32—392 F.	.1150	"
" 32—572 F.	.1218	"
" 32—662 F.	.1255	"
Cast Iron	.1298	Regnault.
Steel, soft	.1165	"
" tempered	.1175	"
Copper	.09515	"
" 32—212 F.	.0927	Dulong & Petit.
" 32—572 F.	.1013	"
Cobalt	.10696	Regnault.
" carburetted	.11714	"
Nickel	.1086	"
" carburetted	.1119	"
Tin, English	.05695	"
" Indian	.05623	"
Zinc	.09555	"
" 32—212 F.	.0927	Dulong & Petit.
" 32—572 F.	.1015	"
Brass	.0939	Regnault.
Lead	.0314	"
Platinum, sheet	.03243	"
" 32—212 F.	.0335	Dulong & Petit.
" at 572 F.	.03434	Pouillet.
" " 932 F.	.03518	"
" " 1832 F.	.03718	"
" " 2195 F.	.03818	"
Mercury, solid	.0319	Regnault.
" liquid	.03332	"
" 32—212 F.	.033	Dulong & Petit.
" 32—572 F.	.035	"
Antimony	.05077	Regnault.
" 32—572 F.	.0547	Dulong & Petit.
Bismuth	.03084	Regnault.
Gold	.03244	"
Silver	.05701	"
" 32—572 F.	.611	Dulong & Petit
Manganese	.14411	Regnault.
Iridium	.1887	"
Tungsten	.03636	"

Digitized by Google

LINEAR EXPANSION. The linear expansion of aluminum is relatively very high, being exceeded only by zinc and lead of the common metals. The table below shows the expansion per degree per unit of length of the various metals in relative order:

COEFFICIENTS OF LINEAR EXPANSION.

AUTHORITY, SIR ROBERTS-AUSTEN.

	CENT.	FAHR.
Potassium	.0000841	.0000476
Sodium	.0000710	.0000395
Indium	.0000417	.0000231
Cadmium	.0000306	.0000170
Thallium	.0000302	.0000168
Lead	.0000292	.0000162
Zinc	.0000291	.0000161
Magnesium	.0000269	.0000150
Aluminum	**.0000231**	**.0000130**
Tin	.0000223	.0000124
Silver	.0000192	.0000107
Tellurium	.0000167	.0000093
Copper	.0000167	.0000093
Bismuth	.0000162	.0000090
Gold	.0000144	.0000080
Nickel	.0000127	.0000071
Cobalt	.0000123	.0000070
Iron	.0000121	.0000069
Palladium	.0000117	.0000065
Antimony	.0000105	.0000058
Ruthenium	.0000096	.0000053
Platinum	.0000089	.0000050
Rhodium	.0000085	.0000046
Iridium	.0000070	.0000039
Osmium	.0000065	.0000036
Arsenic	.0000055	.0000031

Chaney gives the following values of the coefficients of linear expansion, at ordinary temperature, as recalculated by him, and corrected for the author, from selected data, for the Standards Office of the British Board of Trade:

Digitized by Google

	For 1° F.	For 1° C.	Authority.
Aluminum, cast,	**0.00001234**	**0.00002221**	**Fizeau.**
Brass, cast	0.00000957	0.00001722	Sheepshanks.
" plate	0.00001052	0.00001894	Ramsden.
" sheet	0.00001040	0.00001872	Kater.
Bronze, Baileys, Cop. 17; tin 25; zinc 1.	0.00000986	0.00001774	Clarke.
Same	0.00000975	0.00001775	Hilgard.
Copper	0.00000887	0.00001596	Fizeau.
Gold	0.00000786	0.00001415	Chandler & Roberts.
Iridium	0.00000356	0.00000641	Fizeau.
Lead	0.00001571	0.00002828	"
Mercury (cubic expan.)	0.00009984	.0.00017971	Regnault & Miller.
Nickel	0.00004695	0.00001251	Fizeau.
Osmium	0.00000317	0.00000570	"
Palladium	0.00000556	0.00000100	Wollaston.
Pewter	0.00001129	0.00002033	Daniell.
Platinum	0.00000479	0.00000863	Fizeau.
" 90; iridium 10.	0.00000476	0.00000857	"
" 85; " 15.	0.00000453	0.00000815	"
Silver	0.00001079	0.00001943	Chandler & Roberts.
Tin	0.00001163	0.00002094	Fizeau.
Zinc	0.00001407	0.00002532	Baeyer.
" 8; tin 1	0.00001496	0.00002692	Smeaton.

The expansion of the Metals by increase of temperature is exhibited by the following table of *coefficients of linear expansion.*

These figures represent the extension, in parts of its own length, of a bar of the given metal during a rise in temperature from the freezing to the boiling point of water :

	Expansion between 32° F. (0° C.) and 212° F. (100 C.)	Authority.
Glass	0.000872 to 0.000918	Lavoisier & Laplace.
"	0.000776 to 0.000808	Roy & Ramsden.
Copper	0.001712 to 0.001722	Lavoisier & Laplace.
Brass	0.001867 to 0.001890	" "
"	0.001855 to 0.001895	Roy & Ramsden.
Iron	0.001220 to 0.001235	Lavoisier & Laplace.
Steel (untempered)	0.001079 to 0.001080	" "
" (tempered)	0.001240	" "
Cast Iron	0.001109	Roy & Ramsden.
Lead	0.002849	Lavoisier & Laplace.
Tin	0.001938 to 0.002173	" "
Silver (fine)	0.001909 to 0.001910	" "
Gold	0.001466 to 0.001552	" "
Platinum	0.000884	Dulong & Petit.
Zinc	0.002976	Daniell.

Digitized by Google

These coefficients are not absolutely constant, but vary with the physical conditions of the metals. They are not the same with the same material in its forms of cast, rolled, hammered, hardened, or annealed metal. The value of the coefficient of expansion also increases slightly with increase of temperature.

The following table of the principal metals and their properties is extracted from Watts' Dictionary of Chemistry:

CHARACTERISTICS OF METALS.

NAME.	Date of Discovery.	Name of Discoverer.	Sp. G. Water = 1.	Sp. Heat.	Melting Point.	Conductivity. Thermal.	Conductivity. Elect.
Platinum	1741	Wood	21.5	0.0324		8.4	18.
Iridium	1803	Descotils	21.15	0.0326			
Gold			19.26	0.0324	1200° C. (?)	53.2	78.
Mercury			15.60	0.0319	—39° C.		
Palladium	1803	Wollaston	11.80	0.0593		6.3	18.4
Lead			11.33	0.0314	332° C.	8.5	8.3
Silver			10.57	0.0570	1000° C.	100.	100
Bismuth			9.80	0.0308	270° C.	1.8	1.2
Copper			8.94	0.0952	1200° C. (?)	73.5	99.9
Nickel	1751	Cronstedt	8.82	0.1086			13.1
Manganese	1774	Gahn; Scheele	8.02	0.1217			
Iron			7.84	0.1138	2000° C. (?)	11.9	16.8
Tin			7.30	0.0562		14.5	12.4
Zinc			7.13	0.0955	433° C.		29.
Antimony			6.72	0.0508	450° C.		4.6
Aluminum	1828	Wöhler	**2.56**	**0.2143**			**56.1**
Magnesium	1829	Bussy	1.74	0.2499	433° C.		41.2

CONDUCTION OF HEAT. The thermal conductivity of aluminum is very high, and is exceeded by only one of the baser common metals, *i. e.* copper, all the others being less, iron having but one-third as much. The following table gives metals in their order:

RELATIVE THERMAL CONDUCTIVITY.

AUTHORITY SIR ROBERTS-AUSTEN.

Silver	100.00	* **Aluminum**	**31.33**	Lead	8.50
Copper	73.60	Zinc	28.10	Platinum	8.40
Gold	53.20	Cadmium	20.06	Antimony	4.03
Sodium	36.50	Tin	15.20	Bismuth	1.80
Magnesium	34.30	Iron	11.90	Mercury	1.30
		Steel	11.60		

* Wiedermann & Franz give for Thermal Conductivity of
Aluminum annealed 38.87
" unannealed 37.96

Digitized by Google

ELECTRICAL PROPERTIES OF ALUMINUM.

THE ELECTRICAL CONDUCTIVITY OF ALUMINUM. The ELECTRICAL CONDUCTIVITY of silver being taken as 100, that of pure aluminum is about 63.

Aluminum is practically non-magnetic, and may therefore be used for many purposes in electrical work where a magnetic metal would be useless; at the same time its electrical conductivity is excellent, as the following ELECTRICAL CONDUCTIVITIES of various metals will show. Aluminum may therefore in the future be largely used in the windings of field-magnets on dynamos where weight is an object, and in general for switches, brushes, brush-holders, and apparatus where its non-tarnishing and non-corrosive qualities render it specially valuable.

As is the case with other metals of good electrical conducttivity, the conducting power of aluminum is greatly decreased as the result of the presence of alloying metals. Pure aluminum has a much higher relative conductivity to pure copper than is ordinarily given in the books, occasioned by the considerable impurities in the aluminum that has been in the past tested for its relative electrical conductivity.

In the early part of the year 1896, tests made of aluminum wire manufactured by The Pittsburgh Reduction Company, by Mr. Charles F. Scott at the electrical testing laboratory of the Westinghouse Electric Company, and also by Prof. Joseph W. Richards, at Lehigh University, gave the following results in electrical conductivity:

These samples of aluminum were .0282 of an inch in diameter, and of the following composition:

Sample No. 1, ...99.50 per cent. pure aluminum.
" No. 2, ...99.00 " " "

The impurities in each case being chiefly silicon and some
on.

Digitized by Google

Fifty feet of each sample of wire was tested, the wire being wound on wooden spools, and immersed in oil. The temperature was varied by placing the spools so immersed into a steam heater; the oil was kept thoroughly stirred.

Resistance measurements were made by means of a "Wheatstone's Bridge."

The resistance of a soft, pure copper wire one foot long, and one-thousandth of an inch in diameter (unit foot) was taken as 9.720 B. A. units at 0 degrees C.; this corresponding to 9.612 legal ohms at 0 degrees C., or 10.20 legal ohms at 15.5 degrees C.

The results of the tests made, by Mr. Chas. F. Scott, were as follows:

SAMPLE.	Ohms per 1000 feet .01 inch diam. at 15 deg. C.	Per Cent. Conductivity at 15 Deg. C.	% variation per deg. between 15 deg. C. and 80 deg. C.
Pure Copper Wire,	101.83	100.00%	.388
No. 1, 99½ % pure Aluminum,	161.40	63.09 "	.385
No. 2, 99% " "	163.80	62.17 "	.385
Result of Prof. J. W. Richards on the 99½ pure Aluminum	......	64.50 "	.300

Digitized by Google

RELATIVE ELECTRICAL CONDUCTIVITY.

AUTHORITY, SIR ROBERTS-AUSTEN.

Silver, (pure)	100.00	Iron (pure)	14.57
Copper "	97.61	Platinum (pure)	14.43
* " (refined)	97.50	Tin "	14.39
Gold (pure)	76.61	Nickel "	12.89
† **Aluminum** (pure)	**63.00**	**Bronze (10% Alu'm,)**	**12.60**
Magnesium "	39.44	Palladium "	12.08
Sodium "	31.98	* Steel (Siemen's)	12.00
Zinc "	29.57	Thallium (pure)	9.13
Cadmium "	24.38	Lead "	8.42
Calcium "	21.77	Strontium "	6.60
* Brass (35% Zinc)	21.50	Arsenic "	4.68
Potassium (pure)	19.62	Antimony "	3.59
Lithium "	18.68	Mercury "	1.75
Cobalt "	16.93	Bismuth "	1.40
* Iron (Swedish)	16.00	Tellurium "	.0007

* Authority, Lazare Weiler. † Authority, Scott & Richards.

M. Charpentier-Page, in the April 1896 number of "*L'Electrochimie*," publishes electrical conductivity results obtained under his direction, as follows:

ELECTRICAL CONDUCTIVITY.

Pure Copper,	100
Commercially pure Aluminum,	62
Aluminum 97%, Copper 3%,	49
Aluminum 94%, Copper 6%,	44
Aluminum 10%, Copper 90%,	13

The wire tested having a diameter of two millimeters,

IMPURITIES. The impurities most commonly found in aluminum are silicon and iron, and it may be said of the metal made by The Pittsburgh Reduction Co. that these two impurities are the only ones ordinarily found. Silicon in aluminum exists in two forms, one seemingly combined with aluminum as combined carbon exists in pig iron, and the other as an allotropic graphitoidal modification.

Digitized by Google

For many purposes the pure aluminum cannot be so advantageously used as that containing 3% or 4% of alloying metals to harden it, as the pure aluminum is soft and not so strong as the alloyed metal. It is only where extreme malleability, ductility, electrical conductivity and non-corrodibility are required, that the purest metal should be used.

For some purposes, small amounts of copper, nickel, tungsten, manganese, chromium, titanium, zinc or tin, are advantageously added to produce hardness, rigidity and strength—constituents that will not detract from the lightness of the metal and will not affect the non-corrodibility so much as either silicon or iron.

Besides the common impurities of aluminum, there are found in small proportions in commercial aluminum: copper, sodium, carbon, and occluded gases. Nitrogen is specially liable to be present in the metal

These impurities, however, occur in such small quantities in good metal, that their presence need not be considered in commercial dealings.

HARDNESS AND ELASTICITY. The hardness of aluminum varies according to its purity; the purest metal being the softest. The ordinary commercial aluminum is about as hard as copper. Aluminum hardens remarkably when it is being worked, either by pressing, forging, rolling, stamping or other similar treatment. By reason of this the metal may be turned out very rigid in the finished shape, where the soft annealed metal would be too weak to answer the purpose. This is especially true with aluminum containing a few per cent. of some other metals as hardeners. Castings require a larger amount than rolled aluminum of alloying metal in order to increase their hardness. When these castings are drop-forged or hammered, the metal can be produced very rigid and hard.

Great differences are observable between the hardness of the different metals. The results of the experiments of Bottone give valuable information. In his scale, the hardness of the **diamond** was found to be **3010**, whilst the relative hardness of twenty metals was determined with the following results:

Digitized by Google

TABLE OF RELATIVE HARDNESS OF METALS.

Manganese	1456	Gold	979
Cobalt	1450	**Aluminum,**	**821**
Nickel	1410	Cadmium	760
Iron	1375	Magnesium	726
Copper	1360	Tin	651
Palladium	1200	Lead	570
Platinum	1107	Thallium	565
Zinc	1077	Calcium	405
Silver	990	Sodium	400
Indium	984	Potassium	230

In these determinations the time necessary to produce a cut of definite depth was taken as a measure of the hardness of the material, and Bottone concluded that the result so obtained was proportional to the specific gravity of the metal divided by its atomic weight. Metals that possess high limits of elasticity are usually very hard.

ORDER OF DUCTILITY OF METALS.

1. Gold,	4. Iron,	7. Zinc,
2. Silver,	5. Copper,	8. Tin,
3. Platinum,	**6. Aluminum,**	9. Lead.

ORDER OF MALLEABILITY OF METALS.

1. Gold,	5. Tin,	8. Zinc,
2. Aluminum,	6. Platinum,	9. Iron,
3. Silver,	7. Lead,	10. Nickel.
4. Copper,		

Digitized by Google

Prechtl gives the following as the order in which the metals stand :

MALLEABILITY.			DUCTILITY.
	Hammered.	Rolled.	Wire-drawn.
1.	Lead,	Gold,	Platinum,
2.	Tin,	Silver,	Silver,
3.	Gold,	Copper,	Iron,
4.	Zinc,	Tin,	Copper,
5.	Silver,	Lead,	Gold,
6.	Copper,	Zinc,	Zinc,
7.	Platinum,	Platinum,	Tin,
8.	Iron.	Iron.	Lead.

MALLEABILITY. Aluminum is preceded in the relative MALLEABILITY of the metals, only by gold, and in ductility by gold, silver, platinum, iron, soft steel and copper. Both malleability and ductility are impaired by the presence of the two common impurities, silicon and iron. Aluminum of over 99 per cent. purity, is rolled into sheets of only five to seven ten-thousandths of an inch in thickness, and such sheets are hammered into leaf nearly as thin as any gold leaf can be beaten. Aluminum leaf is largely used in decorative work, and on account of its relative cheapness and non-tarnishing qualities has almost entirely superseded the use of silver leaf. Aluminum leaf is ground up into powder and used in large quantities for the pigment of a decorative paint called by the trade "**Aluminum Bronze Paint.**"

Pure aluminum is very SONOROUS, and its tone seems to be improved by alloying with a few per cent. of silver or german silver.

Digitized by Google

SPECIFIC GRAVITY. The specific gravity of aluminum is one of its most striking properties, being 2.56 in ordinary castings of pure aluminum, and 2.68 in the compressed and worked metal. The following is the comparative weight of aluminum with other metals.

SPECIFIC GRAVITY AT 62° FAHRENHEIT OF ALUMINUM AND ALUMINUM ALLOYS.

Aluminum Commercially Pure, Cast	2.56
Nickel Aluminum Alloy Ingots for Rolling	2.72
" " Casting Alloy	2.85
Special Casting Alloy, Cast	3.00
Aluminum Commercially Pure, as rolled, sheets and wire,	2.68
" " " Annealed	2.66
Nickel Aluminum Alloy, as rolled, sheets and wire	2.76
" " " Sheets Annealed	2.74

WEIGHT :

Using these specific gravities, assuming water at 62 degrees Fahrenheit and at Standard Barometric Height, as 62.355 lbs. per cubic foot, (authority Kent and D. K. Clark.)

Sheet of cast aluminum, 12 inches square and 1 inch thick, weighs	13.3024 lbs.
Sheet of rolled aluminum, 12 inches square and 1 inch thick, weighs	13.9259 lbs.
Bar of cast aluminum, 1 inch square and 12 inches long, weighs	1.1085 lbs.
Bar of rolled aluminum, 1 inch square and 12 inches long, weighs	1.1605 lbs.
Bar of aluminum, cast, 1 inch round and 12 inches long, weighs	.8706 lbs.
Bar of rolled aluminum, 1 inch round and 12 inches long, weighs	.9114 lbs.
The weight per cubic inch of Pure Cast Aluminum, is	**.092 lbs.**
The weight per cubic inch of Pure Rolled Aluminum annealed, is	**.097 lbs.**
The weight per cub. ft. of pure cast alum'm is	**159.6288 lbs.**
" " " " " rolled " is	**167.1114 lbs.**

Digitized by Google

Grade of Metal.	Specific Gravity.	Weight per Cubic Foot.
Pure Cast Aluminum	**2.56**	**159.6288***
" Rolled "	**2.68**	**167.1114***
Nickel Alum. Rolli'g Ingots,	**2.72**	**169.606**
" " Rolled Sheets,	**2.76**	**172.10**
" " Casting Metal,	**2.85**	**177.71**
Special Casting Alloy.	**3.00**	**187.40**
Wrought Iron, ...	7.698	480.00
Soft Steel, ...	7.858	490.00*
Cast Iron, ...	7.218 (mean-Kent),	450.78*
" Brass; 33 Zn., 67 Cu.,..	8.320 (" Haswell),	518.79
" Bronze; 16 Tin, 84 Cu.,	8.832 (" "),	550.72
Rolled High Yellow Brass,..	8.549 (" P. R. C.),	533.073*
" Commercial Copper,..	8.93 (A. C. M. A.),	556.83*

*** These values used in calculation of tables.**

Weight of pure rolled aluminum, being 1, (specific gravity 2.68), relative weights of common metals have the following factors of increase in weight:

	Factor.
Tin, specific gravity 7.29 (Roberts-Austen)........	2.720
Wrought Iron, specific gravity 7.698, (Kent).......	2.872
Rolled High Brass, " 8.549, (T. P. R. Co.)	3.190
Rol'd Commer. Copper, " 8.93. (A. C. M. A.).	3.332
Nickel, specific gravity 8.80 (Roberts-Austen)..	3.284
Silver, " " 10.53 " ..	3.929
Lead, " " 11.37 " ..	4.243
Gold, " " 19.32 " ..	7.209
Platinum, " " 21.50 " ..	8.022

Digitized by Google

NICKEL ALUMINUM ALLOY.

Weight of nickel aluminum, cast, being 1, (specific gravity 2.85), relative weights of common metals have the following factors of increase in weight:

	FACTOR.
Cast Iron, specific gravity 7.218	2.533
Cast Brass, 33 zinc, 67 cu., specific gravity 8.320	2.919
Cast Bronze or Composition, 16 tin, 84 cu., specific gravity 8.832	3.099

Weight of rolled nickel aluminum being 1, (specific gravity 2.76), relative weights of common metals have the following factors of increase in weight:

	FACTOR.
Wrought Iron, specific gravity 7.698	2.789
Soft Steel, specific gravity 7.858	2.847
Rolled Brass, High Yellow, specific gravity 8.549	3.097
Rolled Commercial Copper, specific gravity 8.930	3.235

THE SPECIFIC GRAVITY OF ALUMINUM IN COMPARING ITS RELATIVE SELLING PRICE PER POUND WITH THOSE OF OTHER METALS.

It is evident that for any use of aluminum in the form of sheets, bars, tubes, wire or castings, its relative light weight to other metals should be taken into consideration in comparing their relative costs for any given purpose.

The common metals; wrought iron, cast iron, steel, copper, zinc, tin, lead, brass, bronze, german silver, nickel, antimony and brittania metal, are each a great deal heavier, and the relative economy in their use in either the cast or worked shape, can only be arrived at by multiplying the price of the heavier metal, by the factor of its specific gravity relative to the specific gravity of aluminum.

Digitized by Google

TABLE OF SPECIFIC GRAVITY AND UNIT WEIGHTS.

Water at 39.1° Fahrenheit = 4° Centigrade, 62.425 pounds to the cubic foot (authority, Kent, Haswell, and D. K. Clark).

	Specific Gravity.	Authority.	Lbs. per Cubic Foot	Lbs. per Cubic Inch	Kilos per Cubic Decm.
Aluminum, pure cast	**2.56**	**P. R. C.**	**159.63**	**.0924**	**2.56**
" " rolled	**2.68**	"	**167.11**	**.0967**	**2.68**
" " annealed	**2.66**	"	**165.86**	**.0960**	**2.66**
" nickel alloy, cast	**2.85**	"	**178.10**	**.1031**	**2.85**
" " " rolled	**2.76**	"	**172.10**	**.0996**	**2.76**
" " " anne'ld	**2.74**	"	**170.85**	**.0989**	**2.74**
Aluminum Bronze, 10%.	7.70	Riche.	480.13	.2779	7.70
" " 5%.	8.26	"	515.63	.2984	8.26
Brass, cu. 67, zn. 33 cast.	8.32	Haswell.	519.36	.3006	8.32
" cu. 60, zn. 40 "	8.405	Thurston.	524.68	.3036	8.405
Cobalt	8.50	R.-A.	530.61	.3071	8.50
Brass, plates high yellow	8.586	P. R. C.	535.38	.3098	8.586
Bronze composition cu. 90, tin 10	8.669	Thurston.	541.17	.3132	8.669
Bronze composition cu. 84, tin 16	8.832	Haswell.	551.34	.3191	8.832
Lithium	0.57	R.-A.	36.83	.0213	.57
Potassium	0.87	"	54.31	.0314	.87
Sodium	0.97	"	60.55	.0350	.97
Rubidium	1.52	"	94.89	.0549	1.52
Calcium	1.57	"	98.01	.0567	1.57
Magnesium	1.74	"	108.62	.0629	1.74
Caesium	1.88	"	117.36	.0679	1.88
Boron	2.00	Haswell.	124.85	.0723	2.00
Glucinum	2.07	R.-A.	129.22	.0748	2.07
Strontium	2.54	"	158.56	.0918	2.54
Barium	3.75	R.-A.	234.09	.1355	3.75
Zirconium	4.15	"	259.06	.1499	4.15
Selenium	4.50	Haswell.	280.91	.1626	4.50
Titanium	5.30	"	330.85	.1915	5.30
Vanadium	5.50	R.-A.	343.34	.1987	5.50
Arsenic	5.67	"	353-95	.2048	5.67
Columbium	6.00	Haswell.	374.55	.2168	6.00
Lanthanum	6.20	"	387.03	.2240	6.20
Niobium	6.27	R.-A.	391.40	.2265	6.27
Didymium	6.54	"	408.26	.2363	6.54
Cerium	6.68	"	417.00	.2413	6.68
Antimony	6.71	"	418.86	.2424	6.71
Chromium	6.80	"	429.49	.2457	6.80
Zinc, cast	6.861	Haswell.	428.30	.2479	6.861
" pure	7.15	R.-A.	446.43	.2583	7.15
" rolled	7.191	Haswell.	448.90	.2598	7.191

Digitized by Google

TABLE OF SPECIFIC GRAVITY AND UNIT WEIGHTS.—Continued.

	Specific Gravity.	Authority.	Lbs. per Cubic Foot	Lbs. per Cubic Inch	Kilos per Cubic Decm.
Wolfram	7.119	Haswell.	444.40	.2572	7.119
Tin, pure	7.29	R.-A.	455.08	.2634	7.29
Indium	7.42	"	463.19	.2681	7.42
Iron, cast	7.218	Kent.	450.08	.2605	7.218
" wrought	7.70	"	480.13	.2779	7.70
" wire	7.774	Haswell.	485.29	.2808	7.774
Steel, Bessemer	7.852	"	479.00	.2837	7.852
" soft	7.854	Kent.	489.74	.2834	7.854
Iron, pure	7.86	R.-A.	490.66	.2840	7.86
Manganese	8.00	"	499.40	.2890	8.00
Cinnabar	8.809	Haswell.	505.52	.2925	8.098
Cadmium	8.60	R.-A.	536.85	.3107	8.60
Molybdenum	8.60	"	536.85	.3107	8.60
Gun Bronze	8.750	Haswell.	546.22	.3161	8.750
Tobin Bronze	8.379	A. C. Co.	523.06	.3021	8.379
Nickel	8.80	R.-A.	549.34	.3179	8.80
Copper, pure	8.82	"	550.59	.3186	8.82
Copper plates and sheet	8.93	A. of C. M.	556.83	.3222	8.93
Bismuth	9.80	R.-A.	611.76	.3540	9.80
Silver	10.53	"	657.33	.3805	10.53
Tantalum	10.80	"	674.19	.3902	10.80
Thorium	11.10	"	692.93	.4010	11.10
Lead	11.37	"	709.77	.4108	11.37
Palladium	11.50	"	717.88	.4154	11.50
Thallium	11.85	"	739.73	.4281	11.85
Rhodium	12.10	"	755.34	.4371	12.10
Ruthenium	12.26	"	765.33	.4429	12.26
Mercury	13.59	"	848.35	.4909	13.59
Uranium	18.70	"	1167.45	.6755	18.70
Tungsten	19.10	"	1192.31	.6900	19.10
Gold	19.32	"	1206.05	.6979	19.32
Platinum	21.50	"	1342.13	.7767	21.50
Iridium	22.42	"	1399.57	.8099	22.42
Osmium	22.48	"	1403.31	.8121	22.48

Authorities— R.-A..........Prof. Roberts-Austen.
Haswell.....Haswell's Engineer's Pocket Book.
P. R. C......Pittsburgh Reduction Co.'s tests.
Kent.........Kent's Mechanical Engineer's Pocket Book.
Thurston ...Report of Committee on Metallic Alloys of U. S. Board appointed to test iron, steel, and other metals. Thurston's Materials of Engineering.
Riche..........Quoted by Thurston.
A. C. Co......Ansonia Brass and Copper Co.
A. of C. M. .Association of Copper Manufacturers.

Digitized by Google

SPECIFIC GRAVITY OF LIQUIDS AT 60° FAHRENHEIT.

Acid, Muriatic,....	1.2000	Oil, Olive,.........	.92
" Nitric, ...	1.217	" Palm,.... ..	.97
" Sulphuric,....	1.849	" Petroleum,	.78 to .88
Alcohol, pure,.....	.794	" Rape,.........	.92
" 95 %,.. .	.816	" Turpentine,....	.87
" 50 %,....	.934	" Whale,........	.92
Ammonia, 27.9%, .	.891	Tar,...............	1.00
Bromine, ...	2.970	Vinegar,.	1.08
Carbon-Disulphide	1.260	Water, ...	1.00
Ether, Sulphuric,..	.720	Water, Sea,.	1.03 to 1.026
Oil, Linseed,......	.940		

This table is taken from Kent's Mechanical Engineer's Pocket Book.

SPECIFIC GRAVITY AND WEIGHT OF WOOD.

	Specific Gravity.	Average.	Weight per Cubic Foot.
Ash,.........	.60 to .84	.72	45
Beech,.............	.62 " .85	.73	46
Cedar, ...	.49 " .75	.63	39
Cherry,............	.61 " .72	.66	41
Chestnut,...........	.46 " .66	.56	35
Cork,..............	.24 "	.24	15
Ebony,.........	1.13 " 1.33	1.23	76
Hickory, ...	.69 " .94	.77	48
Lignum Vitæ,......	.65 " 1.33	1.00	62
Mahogany, ...	.56 " 1.06	.81	51
Oak, Live,.........	.96 " 1.26	1.11	69
Oak, White,........	.69 " .86	.77	48
Oak, Red,..........	.73 " .75	.74	46
Pine, White,........	.35 " .55	.45	28
Pine, Yellow,.......	.46 " .76	.61	38
Poplar,.............	.38 " .58	.48	30
Spruce, ...	.40 " .50	.45	28
Walnut, ...	.50 " .67	.58	36

This table is taken from Kent's Mechanical Engineer's Pocket Book.

Digitized by Google

SPECIFIC GRAVITY OF DIFFERENT KINDS OF WOOD; WATER BEING UNITY.

FROM GROVES & THORP'S CHEMICAL TECHNOLOGY OF FUELS.

VARIETY OF WOOD.	I. Recently felled.	II. Dried in air.	III. Strongly dried.	IV. Strongly dried.	V. Average Dried.
Common Oak (*Quercus robur*)	1.0754	0.7075	0.6441	0.663	0.929
White Willow (*Salix alba*)	0.9859	0.4873	0.4464	0.457	0.585
Beech (*Fagus sylvatica*)	0.9822	0.5907	0.5422	0.560	0.852
Elm (*Ulmus campestris*)	0.9476	0.5474	0.5788	0.518	0.600
Hornbeam (*Carpinus betulus*)	0.9452	0.7695	—	0.691	—
Larch (*Pinus larix*)	0.9205	0.4735	—	0.441	—
Scotch Fir (*Pinus sylvestris*)	0.9121	0.5502	0.4205	0.485	—
Sycamore (*Acer pseudoplatanus*)	0.9036	0.6592	0.5779	0.618	0.755
Ash (*Fraxinus excelsior*)	0.9036	0.6440	0.6137	0.619	0.734
Birch (*Betula alba*)	0.9012	0.6274	0.5699	0.598	—
Fir (*Pinus abies, Duroi*)	0.8941	0.5550	0.4303	0.493	0.550
Silver Fir (*Pinus picea, Dur.*)	0.8699	0.4716	0.3838	0.434	—
Alder (*Betula alnus*)	0.8571	0.5001	—	0.443	0.800
Black Poplar (*Populus nigra*)	0.7795	0.3656	—	0.346	0.383
Aspen (*Populus tremula*)	0.7654	0.4302	—	0.418	—
Italian Poplar (*Populus italica*)	0.7634	0.3931	0.4402	—	—
Guaiacum Wood	Grif-	1.3420	—	—	—
Ebony	fith.	1.2260	—	—	—

The Following Determinations of the Specific Gravity of Woods were made by Karmarsh.

NAMES OF WOODS.	SPECIFIC GRAVITY.				Mean weight of 1 cubic foot of air-dried Wood in lbs.*
	IN THE GREEN STATE.		IN THE AIR-DRIED STATE.		
	Limits.	Mean.	Limits.	Mean.	
Maple	0.843—0.944	0.893	0.645—0.750	0.697	37 lbs.
Apple	0.960—1.137	1.048	0.734—0.793	0.763	41 "
Pear	....	....	0.646—0.732	0.689	37 "
Red Beech	0.852—1.109	0.980	0.690—0.852	0.771	41 "
Box	....	....	0.912—1.031	0.971	52 "
Cedar	....	....	0.561—0.575	0.568	30 "
Oak	0.885—1.062	0.973	0.650—0.920	0.785	42 "
Ash	0.778—0.927	0.852	0.540—0.845	0.692	37 "
Pine	0.848—0.993	0.920	0.454—0.481	0.467	25 "
Larch	0.694—0.924	0.809	0.565	0.565	30 "
Lime	0.710—0.878	0.794	0.559—0.604	0.581	31 "
Poplar	0.758—0.956	0.857	0.383—0.591	0.487	26 "
Elm	0.878—0.941	0.909	0.568—0.671	0.619	36 "
Willow	0.838—0.855	0.846	0.392—0.530	0.461	25 "
White Beech	0.939—1.137	1.038	0.728—0.790	0.759	40 "

* The Hanoverian pound is equal to 1.031114 lb. English.

Most trustworthy results, obtained by the method ot immersion, have been recorded by Marcus Bull, who took the precaution of covering each specimen with a varnish of sp. gr. = 1.000, which, without giving rise to error, ensured the presence of the whole natural quantity of air in the wood. The most important of his experiments are given in the table below:

Walnut (with scaly bark)	1.000	American Elm	0.580
White Oak and Chestnut	0.885	Virginian Cedar	0.565
American Ash	0.772	Yellow Pine	0.551
Beech	0.724	Birch (poplar-leaved)	0.530
Sassafras	0.618	American Horse-chestnut	0.522
Virginian Cherry	0.597	Italian Poplar	0.397

Digitized by Google

WEIGHT OF A CUBIC FOOT OF VARIOUS SUBSTANCES.

FROM "CARNEGIE'S HAND-BOOK."

Names of Substances.	Average Weight. Lbs.
Anthracite, solid, of Pennsylvania	93
" broken, loose	54
" " moderately shaken	58
" heaped bushel, loose	(80)
Asphaltum	87
Brick, best pressed	150
" common hard	125
" soft, inferior	100
Brickwork, pressed brick	140
" ordinary	112
Cement, hydraulic, ground, loose, American, Rosendale,	56
" " " " " Louisville,	50
" " " " English Portland	90
Coal, bituminus, solid	84
" " broken, loose	49
" " heaped bushel, loose	(76)
Coke, loose, of good coal	27
" " heaped bushel	(38)
Earth, common, loam, dry, loose	76
" " " " moderately rammed	95
Elm, dry	35
Flint	162
Glass, common window	157
Gneiss, common	168
Granite	170
Gravel, about the same as sand, which see.	
Hemlock, dry	25
Hornblende, black	203
Ice	58.7
Ivory	114

Digitized by Google

WEIGHT OF SUBSTANCES.—Continued.

Names of Substances.	Average Weight Lbs.
Lime, quick, ground, loose, or in small lumps	53
" " " " thoroughly shaken	75
" " " " per struck bushel	(66)
Limestone or Marbles	168
" " loose, in irregular fragments	96
Maple, dry	49
Marbles, see Limestones.	
Masonry, of granite or limestone, well dressed	165
" " mortar rubble	154
" " dry " (well scabbled)	138
" " sandstone, well dressed	144
Mica.	183
Mortar, hardened	103
Petroleum	55
Quartz, common, pure	165
Rosin	69
Salt, coarse, Syracuse, N. Y.	45
" Liverpool, fine, for table use	49
Sand, of pure quartz, dry, loose	90 to 106
" well shaken	99 to 117
" perfectly wet	120 to 140
Sandstones, fit for building	151
Shales, red or black	162
Slate	175
Snow, freshly fallen	5 to 12
" moistened and compacted by rain	15 to 50
Sulphur	125
Sycamore	37
Tar	62
Turf or Peat, dry, unpressed	20 to 30
Water, pure rain or distilled, at 60° Fahrenheit	62⅓
" sea	64
Wax, bees	60.5

Green timbers usually weigh from one-fifth to one-half more than dry.

Digitized by Google

SPECIFIC GRAVITY AND WEIGHTS OF LIQUIDS.

RAIN WATER EQUALS 1000.

Calculated upon the basis of a Cubic Foot of Water at 62° F., weighing 62.50 Pounds.

Substances.	Specific Gravity.	Weight of a Cubic Foot.
Liquids.		
Acid, Acetic	1062	66.375
" Benzoic	667	41.687
" Citric	1034	64.625
" Chromic	1521	95.062
" Fluoric	1500	93.750
" Muriatic	1200	75.000
" Nitric	1217	76.062
" Nitrous	1550	96.875
" Phosphoric	1558	97.375
" " solid	2800	175.000
" Sulphuric	1849	115.562
Alcohol, pure, 60°	794	49.622
" 95 per cent	816	51.000
" 80 " "	863	53.937
" 50 " "	934	58.375
" 40 " "	951	59.437
" 25 " "	970	60.625
" 10 " "	986	61.625
" 5 " "	992	62.000
" proof spirit, 50 per cent...60°	934	58.375
" proof spirit, 50 per cent...80°	875	54.687
Ammonia, 27.9 per cent.	891	55.687
Aquafortis, double	1300	81.250
" single	1200	75.000
Beer	1034	64.625
Benzine	850	53.125
Bitumen, liquid	848	53.000
Blood (human)	1054	65.875
Brandy, $\frac{5}{6}$ or .5 of spirit.	924	57.750
Bromine	2966	185.375
Cider	1018	63.625
Ether, acetic	866	54.125
" muriatic	845	52.812
Liquids.		
Ether, nitric	1110	69.375
" sulphuric	715	44.687
Honey	1450	90.625
Milk	1032	64.500
Oil, Anise Seed	986	61.625
" Codfish	923	57.687
" Cotton-seed	—	—
" Linseed	940	58.750
" Naphtha	850	53.125
" Olive	915	57.187
" Palm	969	60.562
" Petroleum	880	55.000
" Rape	914	57.125
" Sunflower	926	57.875
" Turpentine	870	54.375
" Whale	923	57.687
Spirit, rectified	824	51.500
Steam at 212°	.00061	.03818
Tar	1015	63.437
Vinegar	1080	67.500
Water, at 32°	998.7	62.418
" " 39.1°	998.8	62.425
" " 62°	997.7	62.355
" " 212°	956.4	59.640
" distilled 39°	998	62.379
" Dead Sea	1240	77.500
" Mediterranean	1029	64.312
" rain	1000	62.500
" sea	1029	64.312
Wine, Burgundy	992	62.000
" Champagne.	997	62.312
" Madeira	1038	64.375
" Port	997	62.312
Atmospheric Air	.001292	.080728

Digitized by Google

SPECIFIC GRAVITY AND WEIGHTS OF ELASTIC FLUIDS AT ATMOSPHERIC PRESSURE.

ATMOSPHERIC AIR AT 32° = 1.

Substances.	Specific Gravity.	Weight per Cubic Foot.
		Lbs.
Acetic Ether	3·040	·245430
Ammonia	·589	·047557
Atmospheric air, 32°	1·000	·080728
" " 62°	·9426	·076097
Azote	·976	·078805
Carbonic acid	1·520	·122720
" oxyd.	·972	·078482
Carbureted hydrogen	·559	·045136
Chlorine	2·421	·195470
Chloro-carbonic	3·389	·273640
Chloroform	5·300	·428000
Cyanogen	1·815	·146540
Gas, coal	·438	·035360
	·752	·060710
Hydrogen	·0692	·005507
Hydrochloric acid	1·278	·103180
Hydrocyanic "	·942	·076055
Muriatic acid	1·247	·100680
Nitrogen	·972	·078596
Nitric acid	1·217	·098255
Nitric oxyd.	1·094	·088320
Nitrous acid	2·638	·212990
Nitrous oxyd	1·527	·123280
Olefiant gas	·9672	·078100
Oxygen	1·106	·089290

Substances.	Specific Gravity.	Weight per Cubic Foot.
		Lbs.
Phosphureted hydro	1·770	·14291
Sulphureted "	1·170	·09446
Sulphurous acid	2·210	·17843
Steam, 212°	·47295	·03818
Smoke, of bituminous coal	·102	·00823
" coke	·105	·00847
" wood	·090	·00726
Vapor of alcohol	1·613	·13023
" bisulphuret of carbon	2·640	·21315
" bromine	5·400	·43600
" chloric ether.	3·440	·27774
" chloroform	4·200	·33908
" ether	2·586	·20879
" hydrochloric ether	2·255	·18208
" iodine	8·716	·70365
" nitric acid	3·750	·30278
" spirits of turpentine	5·013	·40470
" sulphuric acid	2·700	·21800
" " ether	2·586	·20880
" sulphur	2·214	·17876
" water	·623	·05030

Digitized by Google

COMPARATIVE WEIGHT OF METALS.

Metals.		Weights in Pounds per Square Foot 1 Inch Thick.	Approximate Percentage.	
			Heavier than Iron.	Lighter than Iron.
Iron,	Rolled,	40.000	....	....
Steel,	"	40.833	2 per ct.	...
Aluminum,	"	**13.926**	....	**65.2 per ct.**
Brass,	"	44.43	11.08 per ct.	...
Copper,	"	46.41	16.02 "	....
Gold,	"	100.5	151.25 "	....
Lead,	"	59.15	47.87 "	....
Nickel,	"	45.78	14.45 "	....
Silver,	"	54.78	36.95 "	....
Tin,	"	37.92	....	5.2 per ct.
Zinc,	"	37.21	....	7.0 "

Digitized by Google

STRENGTH.

The tensile, crushing and transverse tests of aluminum vary considerably with different conditions of hardness, due to cold working; also by the amount of work that has been put upon the metal, the character of the section, amount of hardening ingredients, etc. Cast aluminum has about an equal strength to cast iron in tension, but under compression it is comparatively weak. The following is a table giving the average results of many tests of aluminum of 99.0% purity:

		POUNDS.
Elastic limit per sq. in. in tension	(castings)	8,500
" " " "	(sheet)	12,500 to 25,000
" " " "	(wire)	16,000 to 33,000
" " " "	(bars)	14,000 to 23,000
Ultimate strength per sq. in. "	(castings)	14,000 to 18,000
" " " "	(sheet)	24,000 to 40,000
" " " "	(wire)	25,000 to 55,000
" " " "	(bars)	28,000 to 40,000
Per cent. of reduct'n of area in tens'n	(castings)	15 per cent.
" " " "	(sheet)	20 to 30 "
" " " "	(wire)	40 to 60 "
" " " "	(bars)	30 to 40 "

Elastic limit per square inch under compression in cast cylindrical short columns, with length twice the diameter.............................3,500 lbs.

Ultimate strength per square inch under compression in cast cylindrical short columns, with length twice the diameter.........................12,000 lbs.

The modulus of elasticity of cast aluminum is about 11,500,000.

Aluminum in castings, can readily be strained to the unit stress of 1,500 lbs. per sq. inch in compression, and to 5,000 lbs. per sq. inch in tension. It is rather an open metal in its texture; and for cylinders, to stand pressure, an increase in thickness over the ordinary formulæ should be given to allow for its porosity.

Digitized by Google

Under transverse tests, pure aluminum is not very rigid, although the metal will bend nearly double before breaking, while cast iron will crack before the deflection has become at all large.

The texture and strength of aluminum are greatly improved by subjecting the ingots to forging or pressing at a temperature of about 600° Fahrenheit.

Taking the tensile strength of pure aluminum in relation to its weight, it is as strong as steel of 80,000 pounds per square inch. Comparative results in this way are tabulated below as taken from Richards' work on "Aluminium:"

	Weight of 1 cubic foot in pounds.	Tensile Strength per square inch.	Length of a bar able to support its own w't in feet.
Cast Iron	444	16,500	5,351
Ordinary Bronze	525	36,000	9,893
Wrought Iron	480	50,000	15,000
Hard Structural Steel	490	78,000	23,040
Aluminum	**168**	**26,800**	**23,040**

Aluminum wire will have (weight for weight) a conductivity of 200, taking copper as being 100 and aluminum 60. Taking into consideration the comparative tensile strengths of copper, aluminum and the above alloys, and the tension brought upon electrical conductors by having to withstand their own weight, there is a wide field open for aluminum.

NICKEL ALUMINUM ALLOY. The strength of The Pittsburgh Reduction Co.'s "Nickel Aluminum Alloy" is superior to that of pure aluminum, without differing materially from it in weight. Like pure aluminum, the results of tests vary with different conditions—the amount of cold working, character of sections, etc.,—this being particularly true of metal that has been annealed. Under compression and transverse tests, Nickel aluminum is much stiffer than pure aluminum. Generally speaking it should be used in all cases where the greatest strength and rigidity is desired.

Digitized by Google

The following table gives the average results of many tests of Nickel Aluminum.

Elastic limit per sq. in. in tension	(castings),	8500 to 12000
" " " " "	(sheet),	21000 to 30000
" " " " "	(bars),	18500 to 25000
Ultimate strength, per sq. in. "	(castings),	15000 to 28000
" " " "	(sheet),	30000 to 45000
" " " "	(bars),	30000 to 45000
Per cent. of reduction of area.....	(castings),	6 to 8 per cent.
" " "	(sheet),	12 to 20 "
" " "	(bars),	12 to 15 "
Elastic limit lbs. per sq. in. under compression in short columns, with length twice the diam.		6000 to 10000
Ultimate strength lbs. per sq. in. under compression in short columns, with length twice the dia.		16000 to 24000

The following table shows a set of tests of plates of aluminum that were supplied for the American yacht "Defender." These tests were made from actual sections, which were quite thick, and cut from the finished plates two edges of which were left as they came from the rolls, and the other two edges were planed parallel. It will be seen that the sections were about 1½ inches wide, and of the thickness of the plate from which the specimen was taken.

The heaviest plate in the "Defender" weighs about 200 pounds, is 38½ inches wide, $\frac{5}{16}$ of an inch thick, and 13 feet 10 inches long.

This plate gave an ultimate tensile strength of 40,780 pounds per square inch, an elongation of 10 per cent. in two inches, and the reduction of area at the point of fracture was 14.75 per cent.

Except for the color, the fracture of these test specimens is exactly like the fracture of a steel specimen of the same size, tested under the same conditions.

Digitized by Google

Original Dimensions.	Area.	Elastic Limit, Lbs. per sq. inch.	Tensile Strength, Lbs. per sq. inch.	Elongation, 2 inches	Elongation, Per Cent.	Reduction of Area, Per ct.
1.549 x .318	.4926	29,430	41,920	.16	8.	9.1
1.515 x .384	.5818	29,220	43,480	.16	8.	11.5
1.538 x .285	.4383	36,510	39,250	.20	10.	13.50
1.505 x .358	.5386	30,440	40,550	.18	9.	13.1
1.500 x .322	.4856	35,010	39,130	.20	10.	10.9
1.120 x .317	.3550	33,240	39,720	.12	6.	16.7
1.485 x .395	.5866	36,650	36,820	.20	10.	11.6
1.480 x .364	.5387	37,130	39,730	.18	9.	13.6
1.473 x .313	.4610	33,620	40,780	.20	10.	14.75
1.110 x .360	.3996	28,780	39,040	.21	10.50	12.7
1.530 x .384	.5875	27,240	39,240	.20	10.	22.8
1.506 x .366	.5512	30,840	39,730	.18	9.	11.6
1.481 x .389	.5760	30,380	41,320	.16	8.	12.19
1.480 x .324	.4795	25,030	41,200	.21	10.50	15.33
1.478 x .258	.3813	31,470	41,700	.17	8.50	18.45
1.530 x .381	.5830	34,210	40,230	.16	8.	13.4

MODULI OF ELASTICITY OF METALS.

	Pounds per Sq. In.	Kilos per Sq. Cm.
Aluminum,	**11,500,000**	**808,500**
Lead	2,500,000	176,000
Cadmium	7,700,000	492,000
Gold	11,500,000	808,500
Silver	10,000,000	703,000
Palladium	17,000,000	1,195,000
Platinum	24,000,000	1,687,000
Soft Steel	30,000,000	1,828,000
Wrought Iron	26,000,000	2,039,000

STRENGTH OF MATERIALS.

ULTIMATE RESISTANCE TO TENSION IN LBS. PER SQUARE INCH.
FROM "CARNEGIE'S HAND-BOOK."

METALS.

	Average.
Brass, cast,	18000
" wire,	49000
Bronze, or gun metal,	3600c

Digitized by Google

	Average.
Copper, cast,	19000
" sheet,	30000
" bolts,	36000
" wire,	16500
Iron, cast, 13400 to 29000,	16500
" wrought, round or square bars of 1 to 2 inch diameter, double refined, 50000 to	54000
" wrought, specimens ½ inch square, cut from large bars of double refined iron, 50000 to	53000
" wrought, double refined, in large bars of about 7 square inches section, 46000 to	47000
" wro't, plates, angles and other shapes, 48000 to	51000
" " plates over 36″ wide, 46000 to	50000
" wire, 70000 to	100000
" wire-ropes,	90000
Lead, sheet,	3300
Steel, 50000 to	80000
Tin, cast,	4600
Zinc, 7000 to	8000

TIMBER, SEASONED, AND OTHER ORGANIC FIBER.

	Average.
Ash, English,	17000
" American,	16000
Beech, " 15000 to	18000
Box,	20000
Cedar of Lebanon,	11400
" American, red,	10300
Fir or Spruce, 10000 to	136000
Hempen Ropes, 12000 to	16000
Hickory, American,	11000
Mahogany, 8000 to	21800
Oak, American, white, 10000 to	18000
" European, 10000 to	19800
Pine, American, white, red and pitch, Memel, Riga,	10000
" " long leaf yellow, 12600 to	19000
Poplar,	7000
Walnut, black,	16000

Digitized by Google

STONE, NATURAL AND ARTIFICIAL.

Brick and Cement,	280 to 300
Glass,	9400
Slate,	9600 to 12800
Mortar, ordinary,	50

ULTIMATE RESISTANCE TO COMPRESSION.

METALS.

Brass, cast,	10300
Iron, "	82000 to 145000
" wrought,	36000 to 40000

TIMBER, SEASONED, COMPRESSED IN THE DIRECTION OF THE GRAIN.

	Average.
Ash, American,	6800
Beech, "	7000
Box,	10300
Cedar of Lebanon,	5900
" American, red,	6000
Deal, red,	6500
Fir or Spruce,	5000
Oak, American, white	7000
" British,	10000
" Dantzig,	7700
Pine, American, white,	5400
" " long leaf yellow,	8500
Walnut, black,	8000

STONE, NATURAL OR ARTIFICIAL.

Brick, weak,	550 to 800
" strong,	1100
" fire,	1700
Brickwork, ordinary, in cement,	300 to 600
" best,	1000
Granite,	5000 to 18000
Limestone	4000 to 16000
Sandstone, ordinary,	2500 to 10000

Digitized by Google

MODULI OF ELASTICITY.

AUTHORITY.—MECHANICAL ENGINEERS' REFERENCE BOOK, BY NELSON FOLEY.

METALS.

N. B.—For most practical purposes *E* for compression and tension may be taken as the same; it is probable that they would be so if the bar was subjected to repeated shocks both ways.

Metals	Tension. Modulus, lbs. per sq. in. E	Compression. Modulus, lbs. per sq. in. E	Shearing or Torsional. Modulus, lbs. per sq. in. *E*
Brass	13000000		3500000
Copper Wire, unannealed	12000000		3200000
Gun-metal or Bronze	13000000		3700000
Iron, Cast, at 1 ton per sq. in.	13450000	12850000	
" " 2 "	12925000	12750000	
" " 3 "	12400000	12650000	
" " 4 "	11710000	12580000	6300000
" " 5 "	11000000	12470000	
" " 6 "	10100000	12370000	
" " 7 "	9250000	12270000	
Iron, Malleable at 1 ton per sq. in. to	29000000	22400000	10500000
Iron, Malleable " 10 " " to	27600000		
Steel, Mild, Forged or Rolled	30000000	26000000	11000000
" " Cast	30300000		12000000
" Cast, untempered	32000000		11000000
" " tempered	32000000		12000000
Phosphor Bronze	14000000		5250000

WOOD, &c.	Tension. Modulus, lbs. per sq. in. E	Shearing or Torsional. Modulus, lbs. per sq. in. *E*
Ash	1600000	134300
Beech	1350000	140600
Birch	1645000	114300
Elm	1000000	89400
Red Pine	1500000	120000
Yellow Pine	1250000	100000
Larch	1100000	125000
Deal, white		74300
Oak, English	1500000	132000
" American, Red	2150000	
Spruce	1500000	120000
Teak, Indian	2400000	180000
" African	2300000	190000
Leather	25000	

EXAMPLE—A connecting rod of some valve gear, owing to the inertia stresses of the reciprocating parts, as well as the friction of the slide, is subjected to a stress 9000 pounds per square inch at one part of its stroke, if the rod is of forged steel what would be the extension if the normal length was 10 feet?

Taking 10 feet as 120 inches and taking E for steel at 30,000,000, we have $l = \frac{120 \times 9000}{30,000,000} = .004$ of an inch.

SAFE EXTENSIONS OR COMPRESSIONS.

In the case of alterations of length due to stress, it is evident that the maximum stress per unit of section must not exceed the elastic limit of the material

$$\therefore \text{Safe Extension or Compression} = \frac{\text{Length} \times \text{Safe Stress per square inch.}}{E}$$

EXAMPLE—A bar of iron 10 feet long is to be subjected to a tensile stress and it is desired to know what would be the safe extension?

Taking the elastic limit for wrought iron, at 9 tons, we have safe extension $= \frac{10 \times 12 \times 9 \times 2,240}{28,000,000} = .086$ inch.

SHEARING AND BEARING VALUE OF ALUMINUM RIVETS IN POUNDS AVOIRDUPOIS.

Diam. of Rivets in inches.		Area of Rivet.	Single Shear at 4,000 lbs. sq. in.	Shearing Value for Different Thicknesses of Plate at 8,000 lbs. per sq. in. (Diam. of Rivet x Thickness of Plate x 8,000 lbs.)												
Fraction.	Decim'l			1-8 inch.	3-16 inch.	1-4 inch.	5-16 inch.	3-8 inch.	7-16 inch.	1-2 inch.	9-16 inch.	5-8 inch.	11-16 inch.	3-4 inch.	13-16 inch.	7-8 inch.
1-8 inch.	.125	.0123	50	125	185											
3-16 "	.1875	.0276	110	185	280	375										
1-4 "	.250	.0491	195	250	375	500	625									
5-16 "	.3125	.0767	305	310	470	625	780	935								
3-8 "	.375	.1104	440	375	560	750	935	1125								
7-16 "	.4375	.1503	600	435	655	875	1095	1310								
1-2 "	.500	.1963	785	500	750	1005	1250	1500								
9-16 "	.5625	.2485	995	560	845	1125	1410	1685	1970							
5-8 "	.625	.3068	1225	625	935	1250	1565	1875	2185	2500						
11-16 "	.6875	.3712	1485	685	1030	1375	1715	2065	2405	2750						
3-4 "	.7500	.4418	1765	750	1125	1500	1875	2250	2625	3005	3375					
13-16 "	.8125	.5185	2075	810	1220	1625	2030	2435	2845	3250	3660	4065				
7-8 "	.875	.6013	2405	875	1310	1750	2185	2625	3060	3500	3935	4375				
15-16 "	.9375	.6903	2760	935	1405	1875	2340	2810	3280	3750	4220	4790	5155			
1 "	1.000	.7854	3140	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000		
1 1-16 "	1.0625	.8866	3545	1060	1695	2125	2655	3190	3715	4250	4780	5310	5845	6375	6905	
1 1-8 "	1.125	.9940	3975	1125	1785	2250	2810	3375	3935	4500	5060	5625	6185	6650	7310	7875
1 3-16 "	1.1875	1.1075	4430	1185	1880	2375	2970	3570	4155	4750	5345	5935	6535	7125	7715	8315

Digitized by Google

SHEARING AND BEARING VALUE OF ALUMINUM RIVETS IN POUNDS AVOIRDUPOIS.

Diam. of Rivets in inches.		Area of Rivet.	Single Shear at 4,500 lbs. sq. in.	Bearing Value for Different Thicknesses of Plate at 10,000 lbs. per sq. in. (Diam. of Rivet x Thickness of Plate x 10,000 lbs.)												
Fraction.	Decim'l			1-8 inch.	3-16 inch.	1-4 inch.	5-16 inch.	3-8 inch.	7-16 inch.	1-2 inch.	9-16 inch.	5-8 inch.	11-16 inch.	3-4 inch.	13-16 inch.	7-8 inch.
1-8 inch.	.125	.0123	55	155	235											
3-16 "	.1875	.0276	125	235	350	470										
1-4 "	.250	.0491	220	310	470	625	780									
5-16 "	.3125	.0767	345	390	585	780	975	1170								
3-8 "	.375	.1104	495	470	705	935	1170	1405								
7-16 "	.4375	.1503	675	545	820	1095	1365	1640								
1-2 "	.500	.1963	885	625	935	1250	1565	1875								
9-16 "	.5625	.2485	1120	705	1055	1405	1760	2110	2460							
5-8 "	.625	.3068	1380	780	1170	1565	1950	2345	2735							
11-16 "	.6875	.3712	1675	860	1290	1715	2150	2575	3010	3440						
3-4 "	.750	.4418	1990	940	1405	1875	2340	2815	3285	3750	4215					
13-16 "	.8125	.5185	2335	1015	1525	2035	2540	3050	3550	4065	4565	5015				
7-8 "	.875	.6013	2710	1095	1640	2190	2735	3285	3825	4375	4925	5465				
15-16 "	.9375	.6903	3105	1170	1760	2345	2935	3515	4100	4690	5275	5860	6440			
1 "	1.000	.7854	3535	1250	1875	2500	3125	3750	4375	5000	5625	6250	6875	7500		
1 1-16 "	1.0625	.8866	3990	1330	1990	2660	3315	3985	4650	5315	5990	6640	7310	7965	8635	
1 1-8 "	1.125	.9940	4470	1405	2110	2815	3515	4215	4925	5625	6325	7035	7735	8440	9140	9840
13-16 "	1.1875	1.1075	4990	1485	2225	2965	3710	4450	5190	5940	6685	7425	8165	8910	9650	10390

Digitized by Google

ULTIMATE RESISTANCE TO SHEARING.

METALS.

Iron, cast,	25000
" wrought, along the fiber,	45000

TIMBER ALONG THE GRAIN.

White Pine, Spruce, Hemlock,	250 to 500
Yellow Pine, long leaf,	300 to 600
Oak,	400 to 700
Ash, American,	200

ALUMINUM FOR STRUCTURAL PURPOSES.

In the use of aluminum for structural purposes, a great deal depends upon the specific purpose to which it is desired to apply the metal, as to just what is the proper grade that should be used; but generally speaking, for purposes where aluminum is brought into tension, such as in sheets or in rolled shapes, as angles, beams, etc., an ultimate tensile strength of from 32,000 to 40,000 pounds per square inch may be reckoned upon; and using a safety factor of four, gives an allowable working strain of from 8,000 to 10,000 pounds. This of course is not for pure metal, but for the stronger alloys.

The ultimate tensile strength of pure metal in plates and shapes, may be taken at from 24,000 to 28,000 pounds, with the same safety factor of four, it gives an allowable working strain of from 6,000 to 7,000 pounds.

For the alloys of cast aluminum in tension, the ultimate strength may be taken at from 18,000 pounds to 28,000 pounds per square inch; using a safety factor here of five, as aluminum castings are quite uniform and solid, a working strain is obtained of from 3,600 to 5,600 pounds per square inch.

It is difficult to give a value for the ultimate strength of pure cast aluminum in tension, for the reason that while the ordinary pure aluminum will run about 16,000 pounds per square inch, this can be increased very considerably by cold

Digitized by Google

working, and in some cases to as much as to 24,000 pounds per square inch; using a safety factor of five, gives an allowable working strain of from 3,200 to 4,800 lbs.

In compression, the alloys of aluminum in rolled plates and structural shapes, such as struts, columns, etc., have an ultimate tensile strength of from 26,000 to 34,000 pounds per square inch, which using a safety factor of four, gives an allowable working strain of from 6,500 to 8,500 pounds per square inch.

Pure aluminum sheets and structural shapes in compression, have an ultimate tensile strength of from 20,000 to 24,000 pounds per square inch; which, with a safety factor of four, gives an allowable working strain of from 5,000 to 6,000 pounds per square inch.

Castings of aluminum in compression can be taken at 16,000 pounds per square inch for pure aluminum, and from this to 24,000 pounds per square inch for the alloys; using again a safety factor of five, an allowable working strain is given of from 3,200 to 4,600 pounds per square inch. But the pure metal should not be used in castings, except for electrical purposes, as it is similar to pure copper in being difficult to cast, and is soft, comparatively weak, and has a large shrinkage. In its stead, alloys with from five to twenty per cent. of copper, nickel or other hardeners, should be used.

The alloys of aluminum in rivets and similar shapes in shear, have an ultimate shearing strength of from 24,000 to 27,000 pounds; which, using here a safety factor of six, gives an allowable working strain of from 4,000 to 4,500 pounds per square inch.

The ratios of the ultimate shearing strength, to the ultimate tensile strength for double riveted joints, is about 60 per cent.; and for single riveted joints, the ratio is about 70 per cent. The ratio for steel is about 75 per cent.

In bearing, the ultimate value of the alloys of aluminum is from 32,000 to 40,000 pounds per square inch; which, using a safety factor of four, gives an allowable working strain of from 8,000 to 10,000 pounds.

Digitized by Google

The attention of those contemplating the use of aluminum for structural purposes, is called to the fact that the elastic limit is closer to the ultimate tensile strength than in any other of the commercial metals, and for this reason the safety factor of four or five, means a great deal more than it does in steel or iron, where the same safety factor is used.

Where any great strength in aluminum is desired, the metal should be protected in such a way that its temperature is not raised very much beyond that of the ordinary atmospheric temperature, for the reason that aluminum melts at a little less than 1200 degrees Fahrenheit.

The values given above are for temperatures of less than 100 degrees Centigrade (212° Fahrenheit); for temperatures between 100 and 200 degrees Centigrade, the unit strain should be decreased by 50 per cent., and above 200 degrees aluminum should not be designed to be used in strain.

STRENGTH OF GOLD ALLOYS.

The following table of tensile strength of gold with additions of some of the metals, is from Sir Roberts-Austen's work, "An Introduction to Metallurgy."

Name of added Element	Tensile Strength. Tons per sq. inch.	Elongation, Per Cent. (on 3 inches.)	Impurity, Per Cent.	Atomic Volume of Impurity.
Potassium,	Less than 0.5.	Not perceptible	Less than 0.2.	45.1
Bismuth,	0.5 (about)	"	0.210	20.9
Tellurium,	3.88	"	0.186	20.5
Lead,	4.17	4.9	0.240	18.0
Thallium,	6.21	8.6	0.193	17.2
Tin,	6.21	12.3	0.196	16.2
Antimony,	6.0 (about)	qy.	0.203	17.9
Cadmium	6.88	44,0	0.202	12.9
Silver,	7.10	33.3	0.200	10.1
Palladium,	7.10	32.6	0.205	9.4
Zinc,	7.54	28.4	0.205	9.1
Rhodium,	7.76	25.0	0.21 (about)	8.4
Mangan ese,	7.99	29.7	0.207	6.8
Indium,	7.99	26.5	0.290	15.3
Copper,	8.22	43.5	0.193	7.0
Lithium,	8.87	21.0	0.201	11.8
Aluminum,	**8.87**	**2.25**	**0.186**	**10.6**

Digitized by Google

METHODS OF WORKING ALUMINUM.

MELTING. Aluminum is melted in ordinary plumbago crucibles, such as are used for melting brass. If the metal is not overheated, it will absorb no appreciable amount of silicon from the crucible. Aluminum re-melted twenty times in such a crucible, showed only an addition of $\frac{1}{10}$ of one per cent. of silicon.

Aluminum does not unite with or absorb carbon in any considerable quantity when heated in contact with it, unless the metal is heated much above its melting point.

The MELTING POINT OF ALUMINUM is 1,157 degrees Fahrenheit or 625 degrees Centigrade, though at about 1,000 degrees Fahrenheit the metal becomes granular, and can be easily broken. The melting point of copper is 1,053 degrees Centigrade, or 1,929 degrees Fahrenheit, and of cast iron 1,300 degrees Centigrade or 2,372 degrees Fahrenheit.

No flux is needed to cover the metal, for it is non-volatile at any temperature that can be attained with any ordinary coke fire without blast. A very thin film of oxide forms on the surface of the molten metal, which, while not enough to injure either ingots or castings, protects the metal from further oxidation.

SHRINKAGE OF CASTINGS OF METALS.

PURE ALUMINUM, ($\frac{13}{64}$ inch)	.2031	inch	the foot,
"NICKEL ALUMINUM CASTING ALLOY" ($\frac{3}{16}$ inch)	.1875	"	" "
"SPECIAL CASTING ALLOY" of The Pittsburgh Reduction Co., ($\frac{11}{64}$ inch)	.1718	"	" "
Iron, Small Cylinders	.0625	"	" "
" Pipes	.125	"	" "
" Girders, Beams, Etc.	.100	"	" "
" Large Cylinders, Contraction of diameter at top	.625	"	" "
Iron, Large Cylinders, Contraction of diameter at bottom	.083	"	" "
Iron Large Cylinders, Cont'n in length	.094	"	" "

Digitized by Google

SHRINKAGE OF CASTINGS OF METALS.—Continued.

Thin Brass Castings	.167	inch	to the	foot.
Thick " "	.150	"	"	"
Zinc	.3125	"	"	"
Lead	.3125	"	"	"
Copper	.1875	"	"	"
Bismuth	.1563	"	"	"

CASTING. Aluminum, especially in forms where it is alloyed with a few per cent. of hardening ingredients, is now being used very largely in castings of all descriptions, where lightness, non-corrodibility or a silver color is desired. Those alloys most used in general castings have a tensile strength of about 20,000 pounds to the square inch, and are about one-third the weight of brass.

The same general method is followed as in making brass castings. Either iron or sand moulds can be used. The metal should be poured as cold as possible, in order to insure sound castings, free from blow-holes, (caused by the very great absorption of gas by over-heated molten aluminum), or cracks and depressions due to shrinkage. It is also desirable in most cases to use large gates and risers, as a further safeguard against these defects. The gate should be put in such a place on the casting that the metal will not "draw away" where the gate joins the piece. Particular care should be used for this reason in making "gated patterns."

The practice of some moulders is to immerse small quantities of nitre in molten aluminum to purify it, the oxidizing effect of this salt undoubtedly acting somewhat beneficially if care is taken to see that all of the potash salts are allowed to come to the surface and are skimmed off to prevent contamination of the metal. The method of adding nitre in foundry practice is as follows:—After the metal is removed from the fire, and before pouring, slightly dampen a sheet of writing paper in water. Put in this paper one tablespoonful of nitrate of potash, to about one hundred pounds of metal. After the nitrate of potash has been wrapped in this paper, it should be placed on the top of the molten metal, and instantly with an iron ladle or stick, it should be pushed to

Digitized by Google

the bottom of the pot. By the time it reaches the bottom the paper burns, and the nitre comes up through the metal, combining with the oxide as it comes to the surface. It is then skimmed off.

Sulphur is also used to purify from iron, and any other metallic impurities that would form sulphides at the temperature of molten aluminum. Sulphur does not unite with aluminum. Care should be taken however, to free the aluminum from the sulphur thus added.

Some customers of The Pittsburgh Reduction Company make a practice of placing a small amount of benzine on the surface of molten aluminum just as it is about to be cast.

A good method of producing sound castings is that patented by L. J. Crecellius, U. S. Patent, No. 537,277, by which the aluminum is cast in metal moulds, heated to about 1,200 degrees Fahrenheit or about the temperature of the molten aluminum, and causing the metal to cool from the bottom of the moulds upwards by a blast of cold air or other suitable means. Thus, the metal in the comparatively large sinking head or riser remains molten until the casting has solidified. In this way the impurities segregate in the sinking head and the shrinkage is replaced with fresh additions of molten metal.

Charcoal is the best fuel to use in melting aluminum and should be used in all cases where especially good castings are desired. Both coke fires and natural gas are successfully used in melting the metal. Care should always be taken, not only not to overheat the metal, but to prevent the occlusion of gases in aluminum; both nitrogen and hydro-carbon gases are specially liable to be absorbed by molten aluminum. Care should also be taken to have the flasks well vented.

In the casting or working of aluminum, the alloys compare with the pure metal about the same as brass compares with copper.

In general, however, no trouble will be met with in making castings, as the metal flows very readily and takes well to sand.

ANNEALING. In annealing aluminum, an even heat should be maintained in the muffle, and the metal on being withdrawn should be allowed to cool slowly. The temperature should be

Digitized by Google

such that a piece of iron or steel placed in the muffle in the dark will show a red heat; for annealing thin sheet, a much lower temperature will suffice. The best test as to when the aluminum has come to the proper heat is to observe whether the metal will char the end of a pine stick, which should leave a black mark behind it as it is drawn over the plate. The metal should be at this temperature throughout and not only on the surface.

The above remarks apply to the annealing of the pure metal and some of the alloys. Others of the alloys require lower annealing temperature and may be damaged by overheating if treated in the same way as pure aluminum. It is necessary to ascertain the best heat for each alloy by experimenting.

ROLLING. The extreme ductility of aluminum makes it one of the readiest metals to work under the rolls. It is best to roll the larger ingots hot, that is, at a low annealing heat.

Aluminum becomes hard and loses its ductility under rolling, and therefore requires frequent annealing during the process. When the plate is soft from recent annealing, it will stand a very considerable reduction in thickness on each pass through the rolls; but as it becomes hard, the draught must be light to avoid cracking.

Aluminum can be rolled so as to be quite stiff. The hardest rolled aluminum is about the temper of hard brass.

ROLLED ALUMINUM SECTIONS. Aluminum can, either in the pure state or alloyed with a few per cent. of hardening ingredients, be rolled into any sections into which steel is rolled. The Pittsburgh Reduction Company rolls a large number of the more common shapes and sections. In making inquiries for special shapes it must be borne in mind that a great expense is involved in preparing to produce each one and orders for small quantities of them cannot be accepted. In estimating the relative weights of the aluminum to the steel sections, the fact must be borne in mind that sections in steel are based upon a weight of 490 pounds to the cubic foot and that the corresponding aluminum sections will weigh 172 pounds to the cubic foot if of nickel aluminum, the steel being 2.847 times heavier than the similar aluminum section.

Digitized by Google

DROP FORGINGS OF ALUMINUM. Cast aluminum can be very much improved in rigidity and tensile strength, if afterwards subjected to the drop forging process. For special light running machinery, drop forgings of the nickel aluminum casting metal produced by The Pittsburgh Reduction Company, are particularly well adapted.

SQUIRTED ALUMINUM. Aluminum under pressure can be squirted through dies into almost any shape, if the temperature of from 900 to 1,000 degrees Fahrenheit be maintained in the metal. Several devices are used for retaining the heat in the molten aluminum after it is poured into the cylinder in which it is subjected to pressure. In most of these devices the casting cylinder is on trunnions, so that the metal can be poured with the cylinder in a vertical position, after which it is changed to a horizontal position and the piston plunger inserted and made to act on what was the bottom of the ingot as cast, while the die, giving the desired shape to the metal when drawn, is inserted at the other end. An improvement which has been patented in England, is to have the cylinder in which the metal is cast a composite one, consisting of several cylinders of metal, one within the other, the space between the various metal cylinders being filled with some good non-conducting material, which has a high crushing strength; powdered granite is used as a preferable material for the purpose. By means of this device the pressure on the interior metal cylinder is conducted to the outer, thick, cool, and therefore strong cylinders, without the heat of the contained aluminum being conducted away in the same proportion. By means of this apparatus, aluminum can be very cheaply and efficiently squirted to almost any desired section.

POLISHING. An erroneous idea has become prevalent, that aluminum does not require cleaning or polishing.

All metals exposed to the influence of the atmosphere and moisture become tarnished and soiled to a greater or less extent, even though, as is the case with aluminum, the actual oxidation of the surface is almost *nil*. A thin film of "matter out of place," called by housewives by the general name of "dirt," will form upon aluminum as it does upon gold.

Digitized by Google

Almost any good metal polish will cleanse aluminum. It is necessary, however, that the polish should contain no coarse grit. The ordinary metal polishes used for nickel, silver, etc., usually contain too much coarse material and scratch the surface of aluminum.

It will be found that if aluminum has one-half the attention that is given to brass, copper, silver or nickel, it will be kept polished with much less labor and will remain in a brighter condition than any of these metals.

Aluminum will take and retain a very high polish—fully equal to that of silver. The truly distinctive and beautiful color of aluminum is brought out in a highly polished plate. Aluminum can be polished on buffing wheels with rouge, the same as brass; and for polishing any considerable quantity of sheet, this course is the most economical way.

The Pittsburgh Reduction Company, recognizing the necessity of cleaning aluminum, offer for sale a polish, in round aluminum boxes, under the name of "Acme Aluminum Polish" These boxes hold about two ounces each, and can be heartily recommended for general household use. This material is in the form of a paste of a pink color; it is applied with a rag to the metal to be cleaned, rubbing well, then the polish is to be wiped off thoroughly with another rag. A third polishing cloth should be a clean, dry, soft, woolen cloth or chamois skin, to be used in giving the final finish to the metal. The Company sell this same polish in bulk by the pound.

A good polish that has been successfully used consists of the following materials and proportions:

Stearic Acid...........	One part	The whole ground very fine and well mixed.
Fuller's Earth.........	" "	
Rotten Stone..........	Six parts	

Castings are polished by the use of a solid felt wheel, or a muslin wheel, as the nature of the work requires. In either case the wheel should be coated with emery of about No. 100 fineness; the emery being applied in the usual way with glue.

Digitized by Google

For "cutting down" sheets, use a muslin wheel with tripoli. For putting on a fine finish, or "coloring up" either castings or sheets, use a canton flannel buff, with snow flake oil, or some other good coloring rouge.

If a particularly fine surface is desired, in either castings or sheets, it is well to use, after polishing the castings, or after "cutting down" in the case of sheet, a sheep-skin buff, with pumice stone and oil.

SCRATCH BRUSHING AND SAND BLASTING. A brass scratch brush run at a high speed is used on sand castings. This work can be somewhat lessened by first taking a leather wheel and a very fine Connecticut sand, and revolving this wheel at a high rate of speed on a polishing lathe, feeding the sand at the same time between the wheel and the casting, so that the skin and irregularities in the surface are removed; and then putting the casting on a buffing wheel or scratch brushing it. In this way a variety of different effects can be produced. A fine brass scratch brush gives a most beautiful finish to sheet metal or to articles manufactured from the sheet. By this means a frosted appearance is given to the metal, which effect in many cases is equal to that given by a high polish.

An effect similar to the scratch brush finish can be given by sand blasting. The effect of first sand blasting and then scratch brushing sheets, gives a finish with very much less labor than with the scratch brush alone.

Another very pretty frosted effect is secured by first sand blasting, and then treating as hereinafter described under the head of "Dipping and Frosting."

A very pretty mottled effect is secured on aluminum goods, by first polishing them, and then holding them against a soft pine wheel run at a high rate of speed on a lathe. By careful manipulation, quite regular forms can be thus obtained.

This can be varied by first scratch brushing or sand blasting and then holding it against a wheel as above described.

Aluminum which has been sand-blasted receives a grain which will allow of printing on the surface of the sheet with the best results, and aluminum sheets thus prepared, are coming very largely into use for photo-lithographic purposes.

Digitized by Google

The surface in such cases is first sand-blasted in order that it will take and retain the ink, and produce very clear and sharp outlines when printed from.

The faces for cyclometer dials, watch dials, and similar articles, are generally sand-blasted before they are printed upon, which gives a very fine white background.

DIPPING AND FROSTING. Remove the grease and dirt from the plates by dipping in benzine. To whiten the metal and produce a handsome frosted surface, the sheet should be first dipped in a strong solution of caustic soda or potash ; then in a solution of undiluted nitric acid ; then washed thoroughly in water and dried in hot sawdust. The sawdust must be of a fine, dry grade, with no resin or pitch that will streak the surface.

FOR BURNISHING. Use a bloodstone or steel burnisher. For hand burnishing, use either a mixture of melted vaseline and kerosene oil, or a solution composed of two tablespoonsful of ground borax dissolved in about a quart of hot water, with a few drops of ammonia added.

FOR LATHE WORK.

LUBRICANT. The best lubricant to use on aluminum when being turned in the lathe, is either coal oil or water, and in the press when the metal is being drawn or stamped, vaseline.

TOOLING. The best results can be derived in working aluminum by using a "shearing tool," or in other words, a tool which is shaped more resembling one used in working wood, than for working iron or brass, thus securing a tool with a sharp point, which gives the metal an opportunity to free itself, rather than clog the cutting edge. Tools of all descriptions can be made on this principle, regardless of the purpose for which they are intended, whether to cut a thread or turn to a surface.

Benzine is considered the best lubricant on engravers' tools to obtain a bright cut on aluminum, although naphtha, coal oil, or a mixture of coal oil and vaseline is sometimes used. The benzine is preferred, owing to the fact that it does not destroy the satin finish in the neighborhood of the cut, as these other mixtures sometimes do, if they are not carefully handled.

Digitized by Google

There is, however, as much skill required in making and using a tool for a bright cut, as in the choice of the lubricant that is used.

SPEED USED FOR SPINNING OR BUFFING. The best work in spinning aluminum on chucks from five to eight inches in diameter, can be performed by running the lathe at 2,600 revolutions a minute.

Of course, as the diameter decreases for small articles, this speed can be increased up to 3,200 revolutions a minute, and on chucks larger than five or eight inches in diameter, the speed would be decreased somewhat below that given above.

In buffing aluminum, the best work is produced by using a buffer from eight to ten inches in diameter, at a speed of about 3,800 revolutions a minute.

Very fine effects can be produced by first burnishing or polishing the metal, and then stamping it in polished dies, showing unpolished figures in relief.

SOLDERING ALUMINUM. The difficulties in soldering aluminum are occasioned by the following three conditions :

1. Solder does not alloy with aluminum at a low temperature. Solder alloys with copper at approximately 460 degrees Fahrenheit ; but the alloying temperature with aluminum is approximately 200 degrees higher.

2. The heat conductivity of aluminum is high, and the aluminum which is being soldered conveys the heat away from the solder and from the soldering iron, thus rendering difficult the attainment of the soldering temperature.

3. A thin invisible coating of oxide of aluminum instantly forms on the surface of aluminum when it is exposed to the air. In this respect, aluminum is not different from all other metals, as the surface of any metal becomes covered with its oxide immediately after exposure. As is well known, it is necessary to remove this oxide coating in order to permit alloying between solder and the metal, as alloying only takes on a clean surface of metal and the interposing film of oxide prevents the solder from coming into actual contact with the metal.

Digitized by Google

In the case of other metals than aluminum, the oxide coating is removed by means of soldering salts, which dissolve the oxide film. No such soldering salt or flux is apparently discoverable for aluminum, and it is this fact which causes the principal difficulty in soldering it.

Although the oxide coating cannot be removed by fluxing, and if scraped off is immediately replaced, the oxide coating can readily be removed or scraped off by rubbing the surface of the aluminum with a stick of solder; and if the heat is at the same time applied so that the end of the stick of solder is continually melting, the surface of the aluminum will become "tinned" with the solder as fast as the oxide coating is removed and before a new coating can be formed. In other words, the surface of aluminum is "tinned" almost similarly to the "tinning" of other metals when stick solder is used, except that the stick of solder should be continually rubbed over the entire surface of the aluminum, for the purpose of scraping the surface as hard as possible.

After the tinning solder has been applied by the above procedure, it is best to rub it thoroughly into the surface, while still fluid, with a brass scratch-brush. The durability of the joint depends on the thoroughness of the "tinning," and the scratch-brush insures perfect work.

Heat can be applied with either a soldering iron or a blow-pipe, but the blow-pipe or the blast-lamp is preferable, as a soldering iron does not carry sufficient heat to bring large pieces of aluminum to the required temperature, the difficulty of doing which has already been mentioned.

The stick of solder for convenience's sake should be about ¼ inch square.

TO MAKE LAP OR BUTT JOINT BETWEEN TWO SHEETS.— After the surfaces have been "tinned" in the manner above described, there should be melted upon them sufficient quantity of a soft readily flowing solder (pure block tin for instance, or even ordinary half-and-half solder) to furnish all the material necessary for sweating the pieces together. It is impossible to cause solder to flow into an aluminum joint. It must be put just where it is wanted in the first place.

Digitized by Google

After the pieces have been prepared in the manner above described, they can be placed in position and the flame applied long enough to make the solder in the joint thoroughly fluid, after which it is removed and the joint permitted to set, care being taken that the pieces do not move while the solder is still in a fluid condition.

TO SOLDER A SPLICE BETWEEN TWO WIRES. If it is desired to solder a twisted joint between two wires, the wire must be "tinned" before the twisted joint is made, after which the soldering can be done in the ordinary manner. Only in this case it is better to use the "tinning" solder for the whole operation.

TO SOLDER CABLES INTO A SLEEVE OR INTO A SWITCH TERMINAL. Clean and "tin" the wires individually. "Tin" the inside of the sleeve, or terminal, with aluminum solder, if made of aluminum; with half-and-half solder, if made of brass or copper.

If a closed terminal is used, insert the cable and heat, at the same time feeding in stick solder (½ and ½) until terminal is full, remove flame and permit joint to set.

If a sleeve is used, insert the ends of the cable until they meet in the center, seal up the ends of the sleeve with a little fire clay, to prevent escape of the solder, heat the sleeve sufficiently to melt tin, and pour the sleeve full of melted block tin, through a hole previously bored in the center for that purpose.

COMPOSITION OF ALUMINUM SOLDERS. The principal components of successful aluminum solders are tin and zinc, in various proportions. Numerous additions of other materials in small quantities have been recommended by various inventors, the utility of which, however, has never been clearly demonstrated.

The Pittsburgh Reduction Company keeps, for sale, the solder which has thus far produced the best results.

PLATING OF ALUMINUM. The thin coating of oxide which renders soldering difficult also interferes with the plating of

Digitized by Google

aluminum with respect both to the effecting of the deposition of the plating metal and with its durability when the work has been done.

There have been many processes tried with more or less success and some very good work done. These processes are divisible into two classes;

First, those methods in which some means are used for cleaning off the oxide film, and the coating of copper precipitated upon the aluminum by chemical action from aqueous solution or directly by electro deposition.

Second, by dipping the aluminum into a bath of fused double salts of the metal to be deposited, with an alkaline fluoride, or chloride, thus dissolving off the oxide and at the same time depositing a layer of the desired metal by chemical action.

The latter method is a lately patented one and has rather a limited application since many articles will be injured by the temperature to which they are subjected by the fused salts. It is theoretically capable of producing the best results because the fused fluoride dissolves the surface coating of oxide, permitting the precipitation of the desired metal directly upon the aluminum. Practically, however, it is found that the plating takes hold of the aluminum only in spots and that after the lapse of some time rough treatment will cause the plating to peel.

The first method is the one in general use and it is found that the simplest procedure gives the best results.

It is necessary that the surface to be plated should be as clean as possible both mechanically and chemically. If it is possible to do it, the piece should receive a thorough scratch brushing with a dry fine scratch brush.

There is a film of oxide on all rolled, stamped or spun aluminum articles which contains grease and dirt incorporated into the pores and which is very difficult to remove chemically; and, if this is taken off by means of a scratch brush, much more adherent plating results.

The chemical cleaning is accomplished by first dipping for a few seconds in a hot 10 per cent. solution of caustic soda, for removing grease, then rinsing in clear water. After

Digitized by Google

this an immersion is made for about ten seconds in a cold mixture of dilute nitric and hydrofluoric acids, the proper proportions being 85 per cent. water, 10 per cent. nitric acid and 5 per cent. hydrofluoric acid. This dipping effects the solution of the oxide coating and of any silicon which may have been left by the caustic. The piece is again rinsed in clean water, after which it should be immediately put into the "striking bath."

The composition of this plating bath has been the subject of many suggestions and very complex solutions have been tried, but it is the experience of the Pittsburgh Reduction Company that a nearly saturated solution of copper sulphate 75 per cent. and aluminum sulphate 25 per cent. gives the best results. The alkaline cyanides rapidly attack aluminum with the evolution of hydrogen which prevents a retentive plating. The preliminary coating is rapidly put on in the "striking" bath in which the current density should be from 60 to 70 amperes per square foot and the piece should remain in the bath for from 5 to 10 minutes, then removed and whatever loose copper there is, taken off by hard buffing on a dry canton flannel wheel, free from grease.

If there are any spots on the article which are not coppered after this treatment, they should be covered by the use of what is known to the electroplater as a "doctor," which is simply a pad moistened with the electrolyte and mounted on a rod and connected to the positive side of the circuit; the article to be treated being connected to the negative side and the "doctor" applied to the bare spots.

The object of the high current density in the "striking" bath is to cause a deposit over the entire surface. A low density will coat the aluminum only in spots on account of its high electro-motive force of solution which tends to force the current to the originally deposited spots of copper and this tendency is only overcome by the use of a high current density.

After the buffing the piece is immediately rinsed and deposited in the plating bath in which the current should be from two to three amperes per square foot. It should remain there until a coating of sufficient thickness to be impervious to moisture is attained.

Digitized by Google

It can then be polished and prepared for plating in the usual manner of plating copper articles. The preliminary coppering may be done by dipping in a solution of acetate of copper and aluminum chloride, but a precipitated coating is not nearly so retentive as one electrically deposited. Silver, gold and nickel may be plated directly upon aluminum from slightly acid solutions, but the work is not so good as when a copper coating is first applied.

Another process is described in Brannt's translation of Langbein's Electro Deposition of Metals. The translation reads as follows: The best and most reliable method is, without doubt, the one patented in 1893 by Prof. Nees, which consists in first immersing aluminum articles previously freed from grease in caustic soda lye until the action of the lye upon the metal is recognized by gas bubbles rising to the surface. The articles, without being previously rinsed, are then immersed in a solution of 77 Troy grains of chloride of mercury, rinsed, again brought into the caustic soda lye and then, without rinsing, suspended in silver bath.

The deposit of silver thus obtained adheres very firmly and can be scratch-brushed and polished with a steel without raising up. It can also be directly gilded, brassed, or, after previous coppering in the potassium cyanide copper bath, provided with a heavy deposit of nickel and polished upon polishing discs.

GENERAL REMARKS UPON ALLOYS. It is to be noted, that it is not a matter of indiference in what order the metals are melted in making an alloy. Thus, if we combine ninety parts of tin and ten of copper, and to this alloy add ten of antimony; and if again we combine ten parts of antimony and ten of copper, and to that alloy add ninety parts of tin, we shall have two alloys chemically the same, but in other respects—fusibility, tenacity, etc.—they totally differ. In the alloys of lead and antimony also, if the heat be raised in combining the two metals much above their fusing points, the alloy becomes hard and brittle.

Digitized by Google

THE COMMERCIAL METALS Are never chemically pure. Lake Superior copper and the best lead and tin are nearly pure; but all of the other commercial metals have a considerable variety of impurities always present.

THE COMMERCIAL METALS are iron, copper, lead, tin, zinc, aluminum, nickel, antimony, manganese, mercury, chromium, cadmium, magnesium, sodium, potassium, cobalt, bismuth and arsenic; the last eight of these metals, however, are comparatively costly and rare, and little used except for special purposes.

THE COSTLY AND PRECIOUS METALS Are gold, silver, platinum, iridium, palladium, rhodium and ruthenium; they are obtained by special and costly methods of metallurgical treatment in almost perfect purity in commercial quantities.

THE RARE METALS Have never been obtained in commercial quantities at all, and most of them have only been isolated in a considerably alloyed and impure state. The rare metals are calcium, molybdenum, tellurium, titanium, uranium, osmium, thallium, barium, columbium, indium, strontium, didymium, erbium, lithium, cerium, tantalum, gallium, glucinum, boron, thorium, germanium, lanthanum, zirconium, rubidium and vanadium.

ALUMINUM AND THE RARE AND COSTLY METALS. Undoubtedly many of the rare and costly metals will form interesting if not valuable alloys with aluminum. Gold costing $20 per ounce, forms a series of purple and violet colored alloys which will have use in jewelry.

Gallium of the tin group costing $200 an ounce, Thorium $160 per ounce, Germanium $95 per ounce, Rubidium $88 per ounce, Lanthanum $80 per ounce, Glucinum $80 per ounce, Calicum $80 per ounce, Indium and Didymium $72 per ounce, Lithium $64 per ounce, Erbium $62 per ounce, Cerium, Strontium and Zirconium each costing $40 per ounce, and Barium $32 per ounce, are all costly metals, but on account of the extreme difficulties of preserving them from oxidation, are not "precious" or intrinsically valuable. No valuable alloys of these metals with aluminum have yet been discovered.

Digitized by Google

Platinum (costing $15 per ounce) and aluminum, alloy in a very interesting and probably valuable series.

Iridium (costing $10 per ounce) and aluminum, alloy in any proportions, but no valuable alloys have as yet been discovered.

Glucinum on account of its lightness, specific gravity only 2.10, and its high electrical conductivity, which is even higher than that of pure silver or pure copper, is a valuable and will undoubtedly become a useful metal. Glucinum is white, malleable and moderately fusible, resembling aluminum.

Cadmium is a white, malleable and ductile metal resembling tin. Its sulphide, known as cadmium yellow, is bright in color and has qualities of great value to artists. The metal is of little use.

Calcium is yellow, ductile and malleable, and softer than gold. At a red heat it burns with a dazzling white light.

Erbium is very rare; it resembles aluminum in its properties and compounds.

Lithium is a metal resembling silver in color. It admits of being drawn into wire, but has little tenacity. It is remarkable for its lightness and the readiness with which it combines with oxygen.

Molybdenum is a silvery white, brittle and infusible metal. It never occurs native.

Osmium is remarkable for its high specific gravity and infusibility.

Palladium resembles platium. An alloy of 20 per cent. with 80 per cent. gold is perfectly white, very hard and does not tarnish by exposure.

Rhodium is white, very hard and infusible. Its specific gravity is about 11.

Ruthenium resembles iridium. It is rare and of little value.

Strontium is yellowish, ductile and malleable; it burns in the air with a crimson flame.

Thallium is very soft and malleable.

Thorium is an extremely rare metal, remarkable for taking fire below red heat, and burning with great brilliancy; its oxide together with some of the other rare metals, forms a portion

Digitized by Google

of the coating of the mantels of the celebrated "Wellsbach lights."

Titanium is a rare metal, usually obtained as a heavy iron-gray powder.

Tungsten is a hard, iron-gray metal, very difficult of fusion. An alloy of 10 per cent. of this metal and 90 per cent. of steel is of extreme hardness. Both the metal and its compounds have proved of value alloyed in steel and bronze.

Uranium is very heavy and hard, but moderately malleable, resembling nickel and iron; it is unaltered at ordinary temperatures by air or water.

Rubidium and caesium are distributed widely but in small quantities in company with potassium which they resemble closely.

Indium is very soft, malleable and fusible; it marks paper like lead.

Barium, cerium, columbium (or niobium), didymium, lanthanum. tantalum, erbium, yttrium, and zirconium, are all rare metals and not very well known.

ALUMINUM AND OTHER METALS. With the exception of lead, aluminum unites readily with all the common metals, and many useful alloys of aluminum with other metals have been discovered within the last few years. The useful alloys of aluminum so far found have been largely in two groups, the one of aluminum with not more than 15 per cent. of other metals, and the other of metals containing not over 15 per cent. aluminum; in the one case, the metals imparting hardness and other useful qualities to the aluminum, and in the other the aluminum giving useful qualities to the metals with which it is alloyed.

More or less useful alloys have been made of aluminum with copper, chromium, tungsten, titanium, molybdenum, zinc, bismuth, nickel, cadmium, magnesium, manganese, tin and antimony, these alloys all being harder than pure aluminum; but it is by combination of these metals that alloys of most value have so far been discovered.

ALUMINUM AND TIN. Tin has been alloyed with aluminum in proportions of from one to fifteen per cent. of tin, giving

Digitized by Google

added strength and rigidity to heavy castings, as well as sharpness of outline, with a decrease in the shrinkage of the metal. The alloys of aluminum and tin are rather brittle, however, and while small proportions of tin in certain casting alloys have been advantageously used to decrease the shrinkage, on account of the comparative cost and brittleness of the tin alloys, they are not generally used. Sometimes phosphor tin is added to give increased hardness, together with good soldering properties to aluminum alloys.

ALUMINUM AND CHROMIUM. Chromium, though rather expensive, is an especially advantageous hardener of aluminum. Aluminum hardened with chromium seems to retain its hardness after annealing or being subjected to heat, better than almost any other of the alloys.

ALUMINUM AND TITANIUM. Titanium alloys of aluminum, although hard to manufacture uniformly homogeneous, have greater spring and resilience than most other aluminum alloys. Alloys of titanium, chromium and copper, together with aluminum, give some of the hardest and toughest light alloys yet produced.

ALUMINUM AND TUNGSTEN. The alloys of aluminum and tungsten have for the past few years been especially popular for rolled sheets and plates, to be afterwards spun. Under the trade name of "Wolfram Aluminum" the metal has been largely used for military equipments. The alloys of aluminum and tungsten can be advantageously used with the addition of copper, and also with the triple hardeners, tungsten, copper and iron, or tungsten, copper and manganese. As usually made, the aluminum is hardened with some copper; tungstate of soda and ferro-manganese are added to the reducing bath, making an alloy of aluminum, copper, tungsten, manganese and iron.

ALUMINUM AND NICKEL. Nickel alloyed with copper is one of the favorite hardeners used by The Pittsburgh Reduction Company. This alloy, made in the reducing pot with from two to five per cent. of the combined alloying metals, is the most satisfactory all around hard aluminum for rolling or hammer-

Digitized by Google

ing that is produced. In larger proportions of from seven to ten per cent. of the combined hardeners, the best casting metal is produced for purposes where toughness combined with hardness and good casting qualities are desired.

The Pittsburgh Reduction Company sell their malleable hardened aluminum, as well as their toughest casting alloys, under the trade name of "Nickel Aluminum."

Several new nickel and aluminum alloys for jewelers and other special work, have been made. Two of these are :—

(1) 20 parts nickel and 80 parts aluminum.

(2) 40 parts nickel, 10 parts silver, 30 parts aluminum, and 20 parts of tin.

ALUMINUM AND COBALT. Cobalt also acts, with about an equal amount of of copper, as a specially good alloy for hardening aluminum. The following are two cobalt and aluminum alloys used for special purposes :

60 parts cobalt, 10 parts aluminum, 40 parts copper. 35 parts cobalt, 25 parts aluminum, 10 parts iron, 30 parts copper.

GOLD AND ALUMINUM. Professor W. C. Roberts-Austen has discovered a beautiful alloy, composed of 78 parts gold, and 22 parts aluminum, which has a rich purple color.

ALUMINUM COMBINED WITH THE METALLOIDS. While all the metalloids and gaseous elements, such as oxygen, nitrogen, sulphur, selenium, chlorine, iodine, bromine, fluorine, boron, silicon and carbon, unite with aluminum with more or less ease under certain conditions, yet, no useful result has been recorded from the presence of any of these elements with metallic aluminum. The union of the above metalloids in combination with aluminum results in alloys which are very undesirable in every way from a commercial standpoint.

The only advantageous result yet obtained by union of aluminum with any of the metalloids has been in the action of small amounts of phosphorus to aid soldering and in some phosphor aluminum bronzes. The prevention of the occlusion of gaseous metalloids in molten aluminum, and the prevention of the union of carbon with the metal, are among the chief precautions to be observed in the metallurgy of aluminum.

Digitized by Google

ALUMINUM AND THE ALKALI METALS. Due to the ease with which these alloys are decomposed, especially when subjected to water or moist air, none of them can be considered in any way advantageous; in fact, alloys of metallic sodium and potassium with aluminum are the "*bete noir*" of the metallurgy of aluminum, in the same way that sulphur and phosphorus are feared in the metallurgy of steel.

Due to the precautions taken by The Pittsburgh Reduction Company, their metal as sold in the market is especially free from contamination with the metalloids and alloys with the alkali metals.

ALUMINUM AND MOLYBDENUM. Aluminum can be readily alloyed with Molybdenum in the process, by placing the molybdenum oxide in the electrolytic bath with the oxide of aluminum.

Molybdenum acts as a hardener for aluminum, and forms alloys which will have special advantages for some work, as in the production of aluminum coins and medals.

ALUMINUM AND TELLURIUM. When Tellurium is heated with aluminum, the two combine with explosive violence, forming a chocolate colored, difficultly fusible compound, which has the composition of $Al_2 Te_3$. It is hard and brittle, and can readily be ground to powder; when exposed to moist air, it is decomposed and hydrogen telluride with its fetid odor is slowly evolved; when thrown into water, it is rapidly decomposed.

ALUMINUM AND ARSENIC. No specially advantageous compounds of these metals have yet been discovered, nor from the nature of the case are they likely to be, although the metals can readily be alloyed.

ALUMINUM AND SILVER. The addition of a iew per cent. of silver to aluminum, to harden, whiten and strengthen the metal, gives a material especially adaptable for many fine instruments and tools, and for electrical apparatus, where the work upon the tool and its convenience are of more consequence than the increased price due to the addition of the silver. Silver lowers the melting point of aluminum, and gives a metal susceptible of taking a good polish and making fine castings.

Digitized by Google

ALUMINUM AND MERCURY. These metals unite with difficulty, but at the same time amalgams and alloys can be produced by uniting the two metals. No useful results, however, have yet been shown from any of such alloys or combinations.

ALUMINUM AND MAGNESIUM. The alloys of these light metals are interesting and possess some practical advantages. Mixtures of the powders of the two metals have special actinic properties when burned, useful for photographic work. Magnesium being electro-positive to aluminum, will protect it from galvanic action with other metals at the expense of the corrosion of magnesium. The alloys of these two metals, and combinations of them with other metals, will warrant further research as to their advantage.

ALUMINUM AND MANGANESE. Manganese is one of the best hardeners of aluminum ; it can be cheaply added in aluminum casting metal by means of the rich alloys of ferro-manganese. To obtain this alloy for rolling purposes, the pure black oxide of manganese is added to the electrolytic bath in which the aluminum is produced. The alloys of manganese gives special rigidity and hardness to aluminum ; in combination with copper and nickel, one of the hardest alloys of aluminum yet produced has been obtained.

ALUMINUM AND URANIUM. This alloy is an expensive one, and while uranium appears to be a good hardener for aluminum, on account of its expense and rarity, it has not had as yet a general application.

ALUMINUM AND CADMIUM. These metals have been alloyed to produce a solder for aluminum which seems to give good results. Cadmium does not appear to act as a hardener for aluminum as almost all other metals do.

ALUMINUM AND BISMUTH. These two metals combine easily, the alloys being very fusible, as might be expected of alloys with bismuth. They remain unchanged in the air at ordinary temperatures, but oxidize rapidly when melted. Bismuth makes aluminum very brittle. No valuable alloys of these two metals have as yet been discovered.

Digitized by Google

ALUMINUM AND VANADIUM. Vanadium is a good hardener of aluminum, and can readily be alloyed with it, due to its presence in some of the bauxites, the native aluminum ores.

ALUMINUM AND INDIUM. No valuable alloys of these metals have as yet been discovered.

ALUMINUM AND ANTIMONY. These metals unite with difficulty, and only in bearing metals of the class of Babbitt metals, have any useful alloys as yet been discovered.

ALUMINUM AND LEAD. These metals unite only with great difficulty, and no useful alloys have yet been discovered.

ALUMINUM AND ZINC. Zinc is used as a cheap and very efficient hardener in aluminum castings, for such purposes as sewing machine frames, etc. Proportions up to 30 per cent. of zinc with aluminum are successfully used. An alloy of about 15 per cent. zinc, 2 per cent. tin, 2 per cent. copper, ½ per cent. each of manganese and iron and 80 per cent. aluminum, has special advantages.

ALUMINIZED ZINC. Aluminized zinc is used for two purposes, viz: in the bath for galvanizing, and in aluminum brass; and is manufactured as follows:

Take five or ten pounds of aluminum, depending on whether it is desired to make a five per cent. or ten per cent. aluminized zinc, and put it in a plumbago crucible.

After the aluminum is melted, add the zinc, keeping the mass continually stirred until either ninety-five or ninety pounds of zinc has been added, making the total weight of the metal in either case in the crucible, one hundred pounds, or in this proportion. After all the zinc has been added, the crucible should be removed from the fire, and the alloy cast into ingots of any convenient form or size for breaking up.

The five per cent. aluminized zinc will be found best to use in the galvanizing bath, and also in the lower grades of aluminum brass, but in the higher grades of brass containing upwards of one per cent. of aluminum, it would be best to use a ten per cent. aluminized zinc.

Digitized by Google

This aluminized zinc, both in brass and in the galvanizing baths, is treated in all respects the same as pure zinc, as far as the question of introducing it into molten metal is concerned.

THE USE OF ALUMINIZED ZINC IN GALVANIZING BATHS.

The use of aluminum in a galvanizing bath, has become so universal that at the present time it is considered a necessity, in order to produce the best and the most economical work. It is added in the form of aluminized zinc, which is made as described above, and is used in such proportions that the total amount of aluminum in the bath will be about one pound of aluminum per ton of bath, or in using a five per cent. aluminized zinc, twenty pounds of aluminized zinc per ton of bath should be used.

These proportions, however, are varied according to the grade of zinc which is being used, and also upon the class of material to be galvanized ; in some cases more, and some cases less than the quantities given above will be found most advantageous.

When aluminized zinc is used, it has been found unnecessary to use sal ammoniac, for clearing the bath of oxide, as the aluminum accomplishes the same purpose, and if the two are used together, they seem to counteract the effects of each other.

Aluminized zinc should be added to the galvanizing baths gradually, and not all at one time, and as the bath is consumed, fresh aluminized zinc is added in the proportion of about a pound at a time, for a five ton bath. This is when a five per cent. aluminized zinc is used.

The first action of aluminum in galvanizing baths is to make the bath more liquid, which is one of the objects in adding the aluminum ; a greater amount of aluminum seems to combine with the impurities in the zinc, and come to the surface in the form of a scum, which makes galvanizing difficult. If therefore, too much aluminum goes into the bath, stir the bath well, and allow it to stand for a while until the aluminum combines with these impurities and comes to the

Digitized by Google

surface as a scum. Remove this scum, add some sal-ammoniac to counteract the effects of the aluminum, and reduce the proportion of the aluminized zinc added.

In starting with a new bath, it is specially important that these suggestions should be followed.

BRASSES.

Brasses are alloys of copper and zinc, as distinguished from the Bronzes, which are alloys of copper and tin.

A common proportion for making brass is, copper 66 zinc 34. This alloy is a much poorer conductor of electricity and of heat than copper, is more fusible, oxidizes very slowly at low temperatures, but rapidly at a high heat.

It is customary in the manufacture of ordinary commercial brass to introduce from two to five per cent. of tin for the purpose of giving added strength and density.

The terms "high brass" and "low brass" are used in the trade but applied only to wrought material. "High brass" is composed of two parts of copper and one part of zinc and is of a light yellow color.

"Low brass" ranges from 75 per cent. to 88 per cent. copper and 25 per cent. to 12 per cent. of zinc, and in color is considerably darker than "high brass."

The brass of Romilly, which works remarkably well under the hammer, is composed of copper 70, zinc 30; English brass is often given 33 per cent. zinc, and for rolled brass 40 per cent. (This constitutes "Muntz sheathing metal," as patented by G. F. Muntz, in 1832.) The proportion of zinc ranges, however, for such purposes, from 37 to 50 per cent. copper 63 to 50.

All of these alloys are improved by additions of aluminum.

Digitized by Google

Mallet classifies the copper-zinc alloys according to the following table :

PROPERTIES OF COPPER-ZINC ALLOY IN CASTINGS.

Atomic Composition.	Copper by Analy's	Sp. G.	COLOR.	FRACT.	TENACITY Tons per Sq. Inch.	ORDER OF Malleability.	ORDER OF Hardness.	ORDER OF Fus'y.
Cu Zn	pr. ct.							
1 : 0	100.	8.667	red	....	14.6	8	22	15
10 : 1	98.80	8.605	red-yellow	coarse	12.1	6	21	14
9 : 1	90.72	8.607	"	fine	11.5	4	20	13
8 : 1	88.60	8.633	"	"	12.8	2	19	12
7 : 1	87.30	8.587	"	"	13.2	0	18	11
6 : 1	85.40	8.591	yellow-red	fine fibre	11.1	5	17	10
5 : 1	83.02	8.415	"	"	13.7	11	16	9
4 : 1	79.65	8.448	"	"	14.7	7	15	8
3 : 1	74.58	8.397	pale yellow	"	13.1	10	14	
2 : 1	66.18	8.299	deep "	"	12.5	3	23	
1 : 1	49.47	8.230	" "	coarse	9.2	12	12	
1 : 2	32.85	8.263	dark "	"	19.3	1	10	
8 : 17	31.52	7.721	silver white	"	2.1	very brittle	5	
8 : 18	30.36	7.836	silver white	"	2.2	"	6	
8 : 19	29.17	7.019	light gray	"	0.7	"	7	
8 : 20	28.12	7.603	ash "	vitr'ous	3.2	brittle	3	5
8 : 21	27.10	8.058	light "	coarse	0.9	"	9	5
8 : 22	26.24	7.882	" "	"	0.8	"	1	5
8 : 23	25.39	7.443	ash "	fine	5.9	slight duct.	1	5
1 : 3	24.50	7.449	" "	"	3.1	brittle	2	4
1 : 4	19.65	7.371	" "	"	1.9	"	4	3
1 : 5	16.36	6.605	dark "	"	1.8	"	11	2
0 : 1	0.	6.895		....	15.2	....	23	1

In the above table, the minimum of hardness and fusibility is denoted by 1.

The conclusion of Storer that these alloys are mixtures rather than true compounds, is accepted by Watts and others authorities.

ALUMINUM BRASS. Aluminum brass has an elastic limit of about 30,000 lbs. per square inch; an ultimate strength of from 40,000 to 50,000 lbs. per square inch, and an elongation of 3 to 10 per cent. in 8 inches.

Aluminum is used in brass in all proportions from one-tenth of 1 per cent. to ten per cent., and the best results will be derived by introducing when possible this aluminum in the form of aluminized zinc, manufactured as previously described.

Digitized by Google

This aluminized zinc is added in the same manner that the zinc is originally introduced into the copper, and in such proportions as will give the requisite amount of aluminum in the brass mixture.

As stated above, a five per cent. aluminized zinc is generally used when percentages of less than one per cent. of aluminum are required, and aluminized zinc of ten per cent. is used when a greater percentage than one per cent. is required.

The effect of aluminum in brass, added in this manner, in small quantities of less than one per cent., is mainly to make the brass flow freely, and present a smooth surface, free from blow holes. When used in these quantities, from one-half to one-third more small patterns can be used on a gate than can be used without the presence of aluminum, for this amount of aluminum gives to the brass such additional fluidity as enables it to run more freely in the moulds and a greater distance; consequently more patterns can be used on a gate.

In quantities of over about one per cent., the effect of the aluminum commences to be very perceptible, from the fact that it imparts to the brass additional strength, and this strength is increased directly as the percentage of aluminum is increased, up to about ten per cent.

One per cent. of aluminum in brass is very extensively used for electrical purposes, as it gives a brass casting free from pin holes and of greater strength than can be secured otherwise, from the same grade of brass.

It therefore follows that by the use of a small percentage of aluminum in brass, a cheaper grade of brass can be used to do the same work than would otherwise be possible.

In all cases, if MAXIMUM RESULTS are desired, care must be taken that only PURE METALS are used. In this connection it should be clearly understood that much of the copper and zinc commonly used contains a large amount of impurities, and the nature of some of these impurities is such as to absolutely prevent good alloys being made with aluminum. In all cases we would advise customers to insist on an analysis being given of the metal supplied, and for aluminum alloys, to exclude all containing more than one-fourth of one per cent. of

Digitized by Google

iron, arsenic, or antimony, or more than two-hundreths of one per cent. of bismuth. Alloys should be poured at a low heat, as soon as fluid.

It should be noted that the presence of aluminum in these alloys, lowers the point at which they become fluid, and that they are fluid at lower temperatures than either gun metal or ordinary brass mixtures ; therefore the average brass-founder is very liable to overheat them, and great care must be taken to prevent this.

To illustrate the great difference which occurs in metals found in the open market, the following are given as analyses of metals, some of which are good, and others worthless for making good alloys :

ANALYSES OF METALS.

	Best Copper.		Tough Copper.	Bad Copper.		Good Tin.	Bad Tin.		Good Zinc.	Poor Zinc.
Copper......	99.861	99.84	99.67	98.04	98.02	...	...	...	trace	...
Tin..........	.0		...	...	...	98.60	95.55	95.80	.020	...
Zinc	.0	trace	...	...	...	...	...	...	99.656	98.76
Silver..... .	.053	.061	...	...	...	...	...	...	...	...
Lead	.017	.0	...	...	...	.034	.567	3.04	.158	1.09
Bismuth....	.0	.0	.015	...	...	...	...	...	.0	.03
Iron	.030	.0	.018	...	...	.09	.812	.714	.093	...
Nickel......	.039	.05	...	...	...	...	...	...	...	...
Arsenic.....	...	...	.177	1.27	1.40	...	...	...	trace	trace
Antimony	...	...	.0	...	...	trace	2.58	.121	.0	...
Sulphur ...	...	trace	...	...	...	...	...	...	.073	...
Oxygen	...	0.26	...	...	...	...	...	...	...	...

USES OF BRASS. *Brass* is the alloy commonly employed in the arts in the construction of scientific apparatus, mathematical instruments and small parts of machinery. It is cast into parts of irregular shape, drawn into wire, or rolled into rods and sheets. It is harder than copper, very malleable and ductile, and can be "struck up" in dies, formed in moulds, or "spun" into vessels of a wide variety of forms, if handled cold or slightly warm; it is brittle at a high temperature.

Digitized by Google

BRONZES. THE PRINCIPAL BRONZES are those used in coinage, in ordnance, in statuary, in bells, and musical instruments, and in mirrors and the specula of telescopes. These alloys oxidize less rapidly than copper, are all harder, and often stronger and denser.

The addition of a small quantity of tin to copper causes it to become brittle under the hammer, according to Karsten, and the ductility is restored only by heating to a red heat and suddenly cooling. Mushet finds that the alloy, copper 97, tin 3, makes good sheathing, as it is not readily dissolved in hydrochloric acid. The best gun-metal is from copper 90, tin 10, to copper 91, tin 9; if richer in copper, it is especially liable to liquation, which action is detrimental to all these alloys. Bell-metal, copper 80, tin 20, to copper 84, tin 16, is sonorous and makes good castings, but is hard, difficult to work and quite brittle. Suddenly cooling it from a high temperature, reduces its brittleness, while slow cooling restores its hardness and brittleness. It is malleable at low red heat, and can be forged by careful management.

Speculum-metal, copper 75, tin 25, is harder, whiter, more brittle and more troublesome to work than bell-metal.

Old flexible bronzes contain about ¾ of an ounce of tin to the pound of copper, or copper 95, tin 5, as stated by Ure. Ancient tools and weapons, contain from 8 to 15 per cent. tin; medals from 8 to 12 per cent., with often 2 per cent. zinc to give a better color. Mirrors contained from 20 to 30 per cent. tin. The metals, copper and tin, mix in all proportions, and the alloys are, to a certain extent, independent of their chemical proportions. The occurrence of hard, brittle, elastic alloys between the extremes of a series having soft tin and ductile copper at either end, both of which metals are inelastic, is probably a proof that these alloys are sometimes chemical compounds. They are probably compounds in which are dissolved an excess of one or the others of the components.

Digitized by Google

Mallet similarly classifies the copper-tin alloys according to the following table:

PROPERTIES OF COPPER-TIN ALLOYS IN CASTINGS.

At. wt. Cu. — 63.3; Sn.—117.8

Atomic Composit'n	Copper.	Sp. G.	COLOR.	FRACT.	TENACITY Tons per Sq. Inch.	Malleable.	Hard-ness.	Fusibil'y.
Cu Sn	pr. ct.							
1 : 0	100.	8.607	red-yellow	....	14.6	1	10	16
a 10 : 1	84.29	8.561	"	fine grain	16.1	2	8	15
b 9 : 1	82.81	8.462	yellow-red	"	15.2	3	5	14
c 8 : 1	81.10	8.459	"	"	17.7	4	4	13
d 7 : 1	78.97	8.723	pale red	vitreous	13.6	5	3	12
e 6 : 1	76.29	8.750	"	"	9.7	brittle	2	11
f 5 : 1	72.80	8.575	ash gray	conchoid	4.9	"	1	10
g 4 : 1	68.21	8.400	dark gray	"	0.7	friable	6	9
h 3 : 1	61.69	8.539	white gray	"	0.5	"	7	8
i 2 : 1	51.75	8.416	white	lam. grain	1.7	brittle	9	7
j 1 : 1	34.92	8.056	"	vitreous	1.4	"	11	6
k 1 : 2	21.15	7.387	"	lam. grain	3.9	"	12	5
l 1 : 3	15.17	7.447	"	"	3.1	8 tough	13	4
m 1 : 4	11.82	7.472	"	"	3.1	6 "	14	3
n 1 : 5	9.68	7.442	"	earthy	2.5	7 "	15	2
o 0 : 1	0.	7.291	"	....	2.7	....	16	1

a, *b*, *c* are gun-metals ; *d*, hard brass for pins ; *e*, *f*, *g*, *h*, *i*, bell-metal ; *j*, *k*, for small bells.

THE KALCHOIDS, or copper-tin zinc alloys, are of great value, and include the strongest and probably the hardest possible combinations of these metals.

COPPER-TIN-ZINC ALLOYS.

No.	Copper.	Tin.	Zinc.	REMARKS.
1	100	100	100	Very white, brittle, subject to liquation.
2	100	50	50	" but finer grain.
3	100	25	50	Yellowish tint, hard, fine, not malleable.
4	100	25	25	Brittle.
5	100	20	20	Brittle, hard, yellow.
6	100	16	16	" " " close grained.
7	100	14	14	Yellow, slightly malleable.
8	100	12.5	12.5	" more malleable.
9	100	11	11	" " "
10	100	10	10	Fine yellow, fine grain, malleable.
11	100	8	8	Yellow, softer, more malleable.
12	100	7	7	Golden, malleable, soft.
13	100	6	6	" " "

Digitized by Google

The use of 8 to 15 per cent. of tin and 2 per cent. zinc in alloy with copper is probably as common as the employment of the bronzes without zinc; the latter is added to improve the color. Alloys of copper containing from 3 to 8 or 10 per cent. zinc, and from 8 to 15 per cent. tin are used in engineering very extensively, the softer alloys for pump-work, the harder for turned work and for nuts and bearings. An alloy of 5 per cent. tin, 5 zinc, and 90 copper is cast into ingots and remelted for general purposes. It is tough, strong and sound. Copper 75, tin 12, zinc 3, makes a good mixture for heavy journal-bearings. Copper 76, tin 12, zinc 12, is as hard as tempered steel and was made into a razor-blade by its discoverer, Sir F. Chantrey. When copper and brass are mixed in equal proportions and their sum is equal to the weight of tin used, the alloy constitutes a solder.

GERMAN SILVER As made by good makers consists usually of

Copper,	60	per cent.
Zinc,	20	"
Nickel,	20	"
	100	"

This is the composition of almost all German Silver Sheet; but it can be had of any grade with from 4 to 20 per cent. nickel.

German Silver has a specific gravity of 8.50 to 8.60, according to composition.

German Silver rolls cold into sheets. For table utensils to be plated with silver, twenty-five per cent. each of nickel and zinc, to fifty per cent. of copper is usually used.

An alloy consisting of copper 56 per cent., zinc 5 per cent. and nickel 39 per cent., makes a fine white metal of the same class as ordinary german silver.

Aluminum is added to advantage to german silver in varying proportions up to one per cent., the aluminum being first melted with the zinc, as "aluminized zinc."

The aluminum serves to protect the zinc from oxidization, prevents excessive dross, and makes the german silver stronger and somewhat more dense.

Digitized by Google

COPPER ALLOYS.

AUTHORITY.—AN INTRODUCTION TO THE STUDY OF METALLURGY BY W. C. ROBERTS-AUSTEN.

—	COPPER.	ZINC.	TIN.	OTHER CONSTITUENTS.	USES AND REMARKS.
Brass	63 to 72	27 to 34	—		Typical brass.
"	70.29	29.26	0.17	Pb 0.28	Wire. Always brittle if Pb reaches 2 per cent. Tin may vary from 0.1 to 0.5.
Muntz's metal	60 to 62	38 to 40	—		Ship's sheathing.
Sterro metal	55.33	41.80	—	Fe 4.66	Austrian, for ordnance.
Aich's metal	60.00	38.12	—	Fe 1.5	English. Sterro and Aich's metals are remarkable for their great strength, 85,080 lbs. per square inch.
Mosaic gold	65.00	35.00			
Pinchbeck	83.33	16.76			
Mannheim gold	80 to 88	20 to 12			
Gun metal	91.00	—	9.00		For ordnance.
Bell metal	76.50	—	23.50		
" "	74.8	—	25.2		" Big Ben," Westminster.
Speculum metal	70.24	trace.	29.11	Fe, Ni, traces	Telescope mirror, Birr Castle, Ireland.
" "	66.6	—	33.4		
" "	68.1	—	31.9		Ross. Atomic proportion.
Bronze	95.0	1.0	4.0		British bronze coinage.
"	82.7	1.8	4.7	Pb 9.9	Japanese art bronze.
"	71.4	6.0	5.9	Pb 16.3	" " "
"	74.0	10.0	1.0	Pb. 15.0	Chinese Art Bronze.
"	83.5	—	5.15	Pb. 8.3; Fe 3	Prehistoric sword, (Ireland.)
"	94.0	—	5.90	Fe. 0.1	Egyptian chisel.
"	88.46	—	10 04	Pb 1.5	Attic coin.
"	80 to 90	7.0	18 to 12		Bearings for heavy axles.
Aluminum bronze	90.00	—	—	Al 10.0	Tensile strength, 96,434 lbs. per sq. in.
Phosphor bronze	82.20	—	12.95	Pb 4.28; P 0.52	
Manganese bronze	83.45	—	—	Mn 13.48; Fe 1.24; C 0.11	Yellowish grey.
" "	81.03	—	—	Mn 16.86; Fe 1.67; C 0.06	Yellowish white.
Silicon bronze	99.94	—	0.03	Fe Si. trace	Telegraph wire.
" "	97.12	1.12	1.14	Fe trace	Telephone "
Delta metal	55.10	43.47	—	Fe 1.08; Pb 0.37; P 0.10	

Digitized by Google

COPPER NICKEL ALLOYS.

—	Cu.	Ni.	Zn.	Other Constituents.	Remarks.
Nickel coins.....	75.0	25.0			
Packfong......	43.8	15.6	40.6	—	Chinese alloy.
English "German silver,"..	61.3	19.1	19.1		
Berlin argentan	52.0	26.0	22.0		
Sheffield German silver.....	57.0	24.0	19.0		
Platinoid.........	—	—	—	A German silver, with 1 to 2 per cent. of tungsten.	High electrical resistance, not changing with temperature.
Ancient coin....	77.58	20.0	—	Fe 1.04; Co 0.54; Sn 0.03.	Second century, B. C.

TIN ALLOYS.

—	Sn.	Sb.	Cu.	Other Constituents.	Remarks.
Britannia met'l	90.62	7.81	1.46		Birmingham sheet.
White metal.....	82.00	12.00	6.00		For bearings. The composition of white metal is very variable.
" "	53.00	10.60	2.40	Pb 33.0; Zn 1.0	
Ashberry metal	77.8	19.4	—	Zn 2.8	
Pewter............	80.0	—	—	Pb 20.0	
Solder, fine......	66.6	—	—	Pb 33.3	The melting point increases with the proportion of lead.
" tin........	50.0	—	—	Pb 50.0	
" plumbers'	33.3	—	—	Pb 66.6	Authorised by the Plumbers' Company.

Digitized by Google

LEAD ALLOYS.

—	Pb.	Sb.	Sn.	Other Constituents.	Remarks.
Type metal......	70.0	18.0	10.0	Cu. 2.0	
" "	82.0	14.8	3.2	—	For stereotyping.
Bearing metal..	84.0	16.0	—	—	For slowly revolving axles.
" "	60.0	20.0	20.0		
Shot metal.......	99.6	—	—	As. 0.2 to 0.35	

ZINC ALLOYS.

—	Zn.	Sn.	Cu.	Other Constituents.	Remarks.
Antifriction metal............	85.0	—	5.0	Sb 10.0	For bearings.
Babbitt's metal	69.0	19.0	4.0	Sb 3.0; Pb 5.0	(Ledebur.)

BISMUTH ALLOYS, (FUSIBLE METALS.)

—	Bi.	Pb.	Sn.	Cd.	Melting Point.
					C°
Newton's alloys...........	50.0	31.25	18.75	—	95
Rose's "	50.0	28.10	24.64	—	100
Darcet's "	50.0	25.00	25.00	—	93
Wood's "	50.0	24.00	14.00	12.00	66—71
Lipowitz's "	50.0	27.00	13.00	10.00	60

ALLOYS FOR COINAGE.

—	Au.	Cu.	Ag.	Other Constituents.	Remarks.
Gold coin.........	91.66	8.33	—	—	British standard.
" "	90.0	10.0	—	—	"Latin Union" and American.
" "	1.33	82.73	15.93	—	Roman, Septimus Severus, 265 A. D.
" "	40.35	19.63	40.02	—	Early British B.C. 50.
Silver coin........	0.1	7.1	92.5	Pb 0.2	Roman, B. C. 31, almost same as British silver coin.
Silver coin........	—	7.5	92.5	-	British standard.

Digitized by Google

ALUMINUM AND COPPER.

Aluminum and copper form two series of valuable alloys. Aluminum bronze, containing from 2 to 12 per cent. of aluminum; and copper-hardened aluminum, containing from 2 to 15 per cent. of copper.

ALUMINUM BRONZE. The 5 to 10 per cent. aluminum bronzes are among the most dense, finest grained, and strongest alloys known—alloys having remarkable ductility as compared with tensile strength. The 10 per cent. bronze can be made in forged bars, with 70,000 pounds per square inch tensile strength, with 40,000 pounds elastic limit to the square inch, and with at least 25 per cent. elongation in 8 inches. This bronze has a specific gravity of about 7.50, and is of a light-yellow color. The 5 to 7½ per cent. aluminum bronzes of from 8.30 to 8 specific gravity, have a handsome yellow color, and readily give 40,000 to 50,000 pounds per square inch tensile strength, with over 30 per cent. elongation in 8 inches, and with an elastic limit of 20,000 pounds per square inch. It will probably be alloys of the latter characteristics that will be most used—especially in bronze wire and for marine work; and the fact that 5 to 7 per cent. bronzes can be rolled or hammered at a red heat, proper precautions, which can readily be secured, being taken, will add greatly to their use. Alloys of this character can be worked in almost every way that steel can, having for its advantages greater combined strength and ductility, and its greater power to withstand corrosion. The presence of silicon makes a harder bronze, but one of much less comparative ductility and a less malleable alloy. The presence of iron weakens, and very seriously interferes with the value of the bronze. The presence of zinc in the aluminum bronze is not so deleterious—in fact it makes the best aluminum brasses.

Digitized by Google

Aluminum in bronzes lowers the melting-point of the copper at least 100° or 200°. The melting-point of 10 per cent. aluminum bronze is somewhere in the neighborhood of 1,800° Fahrenheit. Aluminum bronze is among the hardest of the bronzes, and hardens upon cold working considerably. This hardness, however, can be lowered by annealing at a red-heat and plunging into cold water. Aluminum bronze can readily be worked in a lathe, the chips cut smooth and long, and do not clog the tool. Aluminum bronze is a remarkably rigid metal under transverse strain, being much more rigid than ordinary brass or even gun bronze, and under compressive strain, although rather low in elastic limit compared with its ultimate compressive strength, it is still much stronger than any of the other bronzes, and there is a long period of gradual compression before finally giving way, making it a peculiarly safe metal under compression.

Sound castings can be made with aluminum bronze if the precautions are taken to avoid the difficulties which are particularly imminent in melting.

1st. Care must be taken not to overheat the metal, for if the metal is heated to too high a temperature, the aluminum will oxidize; the aluminum oxide which is formed, making the entire casting "dirty." The metal will also be spongy from the presence of large amounts of occluded gases.

2nd. The scum which floats on top of the melted bronze in the crucible must be prevented from going into the body of the casting. This is accomplished by providing the casting with suitable skim gates.

3rd. The greatest trouble in making bronze castings, however, arises from the shrinkage of the metal, which is very excessive; but the difficulty can be overcome if the casting is given a large sinking-head and "risers." It is necessary to make the sinking-head fully as large as the casting, in many cases.

ALLOYS WITH SMALL PERCENTAGES OF COPPER.

Copper in proportions of from 2 to 15 per cent. has been advantageously used to harden aluminum in cases where a more rigid metal is required than pure aluminum. Copper

Digitized by Google

is the most common metal used at present to harden aluminum. A few per cent. of copper decreases the shrinkage of the metal, and gives alloys that are especially adapted for art castings. The remainder of the range, from 20 per cent. copper up to over 85 per cent., give crystalline and brittle grayish-white alloys of no use in the arts. After 80 per cent. copper is reached, the distinctly red color of the copper begins to show itself.

THE MANUFACTURE OF ALUMINUM BRONZE.

In the manufacture of aluminum bronze, the best results will be derived by following closely the following method of manufacture:

Both the copper and the aluminum should be carefully selected, and none but the purest Calumet and Hecla Mine or "Lake" copper should be used and the aluminum should be guaranteed to be at least ninety-nine per cent. pure.

The copper should be put in a plumbago crucible, and melted over a charcoal or coke fire; these being the best fuels to use. Next to charcoal or coke comes oil, and then natural gas or producers gas as a fuel for melting. It is impossible to make satisfactory aluminum bronze over an ordinary coal fire, for the reason that the copper will absorb the gases from the coal. The copper should be covered with charcoal to prevent oxidation and the absorption of gases as far as possible, as there is always the liability of a small amount of gases being present, even in using the fuels previously mentioned.

After the copper has been melted, and the time has arrived to put in the aluminum, the crucible should be taken hold of with tongs in order to remove from the fire instantly and the percentage of aluminum which it is desired to add, is dropped into the pot through the charcoal.

In large pots of bronze, the pot may be removed from the fire before adding the aluminum. As soon as the aluminum

Digitized by Google

goes into the pot, the first action will be a cooling one to a certain extent, caused by the actual temperature of the aluminum, but as aluminum and copper form natural alloys, the aluminum as soon as it is heated to its melting temperature, goes into combination with the copper, and consequently a great deal of latent heat is set free or made sensible by the chemical union of these two metals, and consequently the temperature of the mass is raised.

If the mixture is watched, one can tell as soon as union takes place, for the reason that the copper will become more liquid, and also turn a little brighter.

This is only an instant after the aluminum is introduced, then if the crucible has remained on the fire, it should be removed instantly, the charcoal skimmed from the surface, and the contents, which is now aluminum bronze, poured into moulds of any convenient size, keeping the liquid stirred as much as possible until poured.

After this aluminum bronze has become cold, it should be remelted and poured into moulds as desired, for the purpose of manufacturing finished castings.

After aluminum bronze is made, it improves with each successive re-melting and casting, until this has been accomplished three or four times, for the reason that it seems to give the aluminum a better chance to become more freely disseminated, and form a more uniform alloy with the copper.

After putting the aluminum into the crucible, and before pouring, the molten mass should be stirred, in order to insure that the aluminum is as well disseminated through the alloy as possible.

If these points are strictly adhered to, good castings can be produced.

The percentage of aluminum in aluminum bronze varies from a few per cent. up to ten, or eleven per cent., depending for what purpose the metal is intended. The strongest mixture is between ten per cent. and eleven per cent. Beyond this point the bronze is hard to work, and becomes brittle.

Aluminum Bronze can be readily soldered. There is not the difficulty in soldering this that there is with pure aluminum.

Digitized by Google

The best method of soldering aluminum bronze is to use pure block tin with a flux of zinc filings and muriatic acid. It is well to " tin " the two surfaces before putting them together.

NICKEL BRONZE. An alloy of 70 per cent. copper, 23 per cent. nickel, and 7 per cent. aluminum, has a fine yellow color and takes a high polish, a small percentage of phosphorus considerably hardening the alloy.

ALUMINUM BEARING METAL. Additions of ½ to 2 per cent. of aluminum to Babbitt metal with a composition of copper 3.7 per cent. antimony 7.3 per cent., tin 89 per cent., gives a very superior bearing metal.

ALUMINUM AND IRON. Aluminum combines with iron in all proportions. Few of the alloys, however, have yet proved of value, except those of small percentages of aluminum with steel, cast iron and wrought iron. Small amounts of iron have been used with advantage in some casting alloys of aluminum. An alloy of aluminum with a small percentage of copper, tungsten and iron has been shown to have some advantages for rigidity and strength. Iron as a ferro alloy of chromium, manganese or similar metals, is a convenient and cheap metal to use in hardening aluminum alloys. So far as experiments have yet gone, as a general proposition, other elements can better be employed to harden aluminum than iron, and its presence in aluminum is usually regarded as deleterious and to be avoided if possible. There are very few commercial metals not chemically pure containing as little iron as does aluminum as made by The Pittsburgh Reduction Company ; certainly all of the brasses, bronzes or German silvers, contain a larger percentage of iron.

ALUMINUM IN STEEL. Aluminum is largely used in the manufacture of steel, the amount of aluminum used, however, being small. The amount of aluminum used to give the best results varies with the grade of steel, amount of occluded gases, temperature of the molten metal, etc.

Aluminum is usually added in proportions of from one-eighth to three-quarters of a pound to the ton of steel ; the

Digitized by Google

aluminum being added either in the ladle, or in the case of steel castings, with more economy of the aluminum as the metal is being poured into the ingot moulds or groups of moulds.

Until the proper percentage of aluminum to add to any particular grade of steel has been determined, it is advisable to start with small lots, for instance, with two or three ounces to the ton, working up to the proportion that seems to give the best results.

The special advantages to be gained by the use of aluminum in steel manufacture are enumerated as follows:

1. The increase of soundness of tops of ingots and consequent decrease of scrap and other loss, which more than compensates for the cost of the small amount of aluminum added.

2. The quieting the ebullition in molten steel, thereby allowing the successful pouring of "wild" heats from furnaces, ladles, etc.

3. The aid to the homogeneity of the steel;

(a)—By preventing oxidation;

(b)—By that property of aluminum by which it rapidly permeates the body of the steel, thereby increasing the ease with which other metals will alloy homogeneously with steel;

(c)—By decreasing the time that steel will remain fluid after being poured into moulds, and causing the steel when solidifying to do so more evenly, preventing a central core remaining molten longer than the outside portion of the metal, and in this way stopping the segregation of phosphorus and other impurities in the "mother liquor" of the metal remaining molten the longest.

4. The increase of the tensile strength of steel without decrease of the ductility.

5. The removal of any oxygen or oxides that there may be in the steel, the aluminum acting in the same way as manganese does as a deoxidizer. Good steel has been made for electrical purposes, using aluminum entirely in the place of manganese, to remove the oxidation from the molten steel and render it malleable.

Digitized by Google

6. The rendering steel less liable to oxidation. This is occasioned by preventing the continued exposure of fresh surfaces of the molten steel in its ebullition in the moulds after pouring.

7. The production of smoother surfaced castings and ingots of steel than it is possible to obtain without the use of aluminum.

There are no such metals as "aluminum steels," in the same way that there are "nickel steels" and "chromium steels." Aluminum is not a hardener of steel, and none of its alloys with steel in material proportions have so far proven advantageous. It has been proved that the addition of aluminum to the steel just before "teeming" causes the metal to lie quiet, and give off no appreciable quantity of gases, producing ingots with much sounder tops. There are two theories to account for this: one, that the aluminum decomposes these gases, and absorbs the oxygen contained in them; the other is that aluminum greatly increases the solubility in the steel of the gases which are usually given off at the moment of setting, thus forming blow-holes and bubbles.

Probably both of these causes operate to produce the desired effect, but the well known affinity of aluminum for oxygen would point to the former as being the chief action, *i. e.*, in combining with both the carbonic oxide and the dissolved oxide of iron which may be present. Professor Arnold has shown that blowholes in steel and iron are partly caused by the presence of carbonic oxide gas in the metal, and this gas is decomposed by the aluminum which unites with the oxygen, forming alumina, or oxide of aluminum, setting free the carbon, which appears as uncombined carbon or graphite. It also combines, in some way not yet determined, with the hydrogen and nitrogen present, absorbing these gases or rendering them more soluble in the steel. Aluminum also sets free much of the remaining carbon in the steel, as the following result obtained by Mr. R. A. Hadfield will clearly show. Believing that aluminum, like silicon, would cause a precipitation of graphite, he added between three and four per cent. to ordinary spiegel, (12 and 25 per cent. manganese). The

Digitized by Google

result was in both cases a complete change from the well-known spiegel fracture to that of ordinary close No. 3 grey pig iron.

	C. C.	Gr. C.	Si.	Mn.	Al.	
SPIEGEL.						
12 % before addition of Al............	4.80	none.	—	13.65	—	Non-magnetic susceptibility unaltered. Fract'e changed from usual pronounced "spiegel" appearance to that of No. 3 iron.
12 % after addition of Al............	.93	3.45	1.30	11.75	3.19	
25 % before addition of Al............	4.10	—	—	25.20	—	Do. except the change was not quite so decided. There was considerable loss of alumin'm
25 % after addition of Al............	2.30	1.88	2.16	22.16	1.24	

Aluminum is the principal deoxidizer known to metallurgists, the next being silicon; their relative values being shown as follows:—100 parts by weight of oxygen will combine with 114 parts of aluminum, or with 140 parts of silicon, or with 350 parts of manganese. This, however, does not correctly express the value of aluminum as a deoxidizer of iron and steel, as it has such a great affinity for oxygen that it will entirely disappear if there is any oxygen present, and will only be found in the steel and iron after all the oxygen has been absorbed. This is not the case with either silicon or manganese, as either or both of these are often found in the steel when oxygen is present. There is also an additional inducement to use aluminum, namely, in the cost, for the use of silicon will add from 87 cents to $1.12 to the cost per ton of steel, while sufficient aluminum will not add over 20 cents, and in many cases not more than 10 cents per ton to the cost of the steel. The saving in bad castings, or unsound ingots, will repay this many times over. One large English steel maker estimates his saving at over £2,000 per annum from this source alone. The special advantage seems to be that aluminum combines the effects of both silicon and manganese to the steel maker.

There is danger of adding too large a quantity of aluminum, in which case the metal will set very solid and will be liable to form deep "pipes" in the ingots. To add just the right pro-

Digitized by Google

portion of aluminum requires some little experience on the part of the steel manufacturer, but successful results have been secured with varying kinds of steel by adding from one-eighth to three-quarters of a pound of aluminum to the ton of steel. No difficulty has been experienced with the thorough mixing of the aluminum added to steel, as it seems to rapidly and uniformly permeate the steel without any special pains being taken in stirring. This property adds to the homogeneous alloying of nickel to steel as well, and the nickel-steel manufacturers use aluminum in addition to nickel for this purpose. If the metal be "wild" in the ladle, full of occluded gases, too hot, or oxidized, a larger proportion of aluminum can be advantageously added. Mr. R. A. Hadfield says that the influence of aluminum in steel appears to be like that of silicon, though acting more powerfully. The same writer, together with Howe and Osmund, claim that an addition of aluminum does not lower the melting point of steel; *i. e.*, that the critical point is about the same whether aluminum is present or not, but it is certain that when once melted, the alloys containing small percentages of aluminum are far more fluid than those without it. It is the aim, however, in adding aluminum to iron or steel, to add just sufficient to combine with all the oxygen present, but leave no trace in the ingot or casting; any more than this is not required.

Mr. J. E. Stead states that in a case where aluminum had been added to ordinary soft open-hearth steel with properly prepared moulds, the castings were very sound indeed. The test bars, which were cast about eight inches long by three-quarters of an inch square, were perfectly sound and had a tensile strength of 40,000 lbs. per square inch, whereas the same bar, without aluminum, only stood 20,000 lbs., the reason being that in the ordinary steel without aluminum the cavities were very numerous. One-tenth per cent. of aluminum in that casting increased the weight and solidity, and reduced the blow-holes by 23 per cent.

In the manufacture of steel ingots, too large a proportion of aluminum added causes excessive piping and loss by increase of crop-ends, occasioned thereby. With steel ingots to be

Digitized by Google

afterwards hammered or rolled, from two to four ounces of aluminum to the ton of steel has been found to be the most advantageous in producing ingots which have sound tops. In the manufacture of steel castings, where the first desideratum is soundness of the castings and freedom from blow-holes, and where the excessive piping and contraction in cooling is provided for by large runners and high and capacious fountain or "sinking head," as they are called in foundryman's parlance, larger amounts of aluminum, up to 16 or even 32 ounces of aluminum to the ton of steel, are advantageously added.

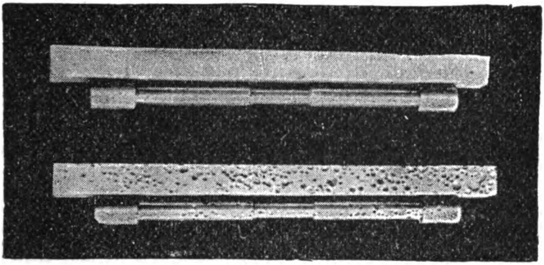
A valuable alloy of aluminum and ferro-manganese has lately been patented, the addition of a small percentage of aluminum to the ferro-manganese rendering the combined carbon, in the manganese alloy, graphitic, and throwing it out of the molten mass. This permits of the production of a ferro-manganese very low in combined carbon, and it is particularly useful in the manufacture of low carbon steel.

Professor Arnold states that his experiments show clearly that the effect of even small quantities of aluminum in producing steel free from blowholes is perhaps the most remarkable phenomenon in the metallurgy of steel. Its action is about twenty times as powerful as that of silicon, and the resultant steel is far superior in ductility and toughness. The action of aluminum is almost certainly chemical.

He also illustrates the remarkable results obtained by the use of aluminum with the following cuts:

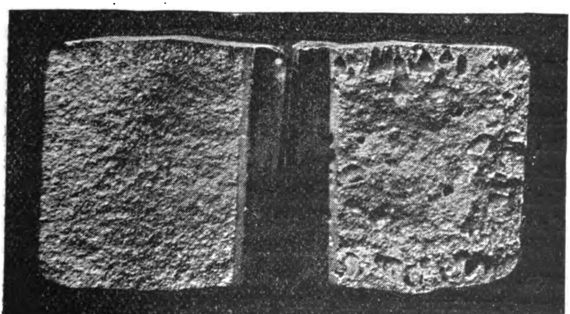
Digitized by Google

A melted from Bessemer spring scrap only. Composition: **C.** 0.62, Si. 0.27, Mn. 0.46, S. 0.11, P. 0.08.



A exactly same as **B**, but 0.1 per cent. aluminum added five minutes before casting. Composition: C. 0.64, Si. 0.29, Mn. 0.62, S. 0.10, P. 0.08, Al. 0.04.

The following illustration of broken ingots shows clearly the effect of aluminum in producing better and more valuable ingots:



The two ingots are identical, except the addition of .05 per cent. of aluminum to the left-hand ingot.

Aside from the reduction of blowholes, and consequent greater soundness, the addition of about 1 pound of aluminum

Digitized by Google

per ton of steel, is of advantage where the steel is to be cast in heavy ingots which will receive only scant work. Here it seems to increase the ductility as measured by the elongation and reduction of area of tensile test specimens, without materially altering the ultimate strength.

In steel castings the benefit from the use of a small percentage of aluminum has become widely recognized, and it is being generally used. The additions of aluminum are in many instances made by throwing the metal, into the ladle, in pieces weighing a few ounces each, as the steel is poured into it.

This, however, is not always the method used to introduce the aluminum, and some manufacturers prefer to add the aluminum in the form of ferro-aluminum; in this case the alloy is first placed in the ladle, and as the molten steel runs in, the alloy melts. and is diffused through the entire contents of the ladle.

FERRO-ALUMINUM. This is the trade name given to alloys of from five to ten, or even twenty per cent. of aluminum added to iron. These alloys vary in quality occasioned by the grade of steel or iron used in making them. Either a good grade of cast iron, free from sulphur and phosphorus, or of pure steel low in these elements, is the best material used for this purpose. For most cases, in either steel making or foundry work, the use of pure aluminum is most general in American practice. It has the advantage, in that the consumer knows more exactly the amount of aluminum he is adding, and avoids the disadvantage of the addition of a considerable amount of iron of a quality foreign and perhaps injurious to his mixture.

The English practice favors more the use of ferro-aluminum, specially in foundry work, but it is believed among many American iron and steel founders, that this is more a prejudice and the result of having first used ferro-aluminum alloys which used to be sold cheaper for the contained pure aluminum. This is not now the case, and pure aluminum can be bought as cheaply as the contained aluminum in any of the ferro-aluminum alloys.

Digitized by Google

ALUMINUM IN CAST IRON. In cast iron, from one to two pounds of aluminum per ton is put into the metal as it is being poured from the cupola or melting furnace. To soft gray No. 1 foundry iron it is doubtful if the metal does much good, except, perhaps, in the way of keeping the metal melted for a longer time; but where difficult castings are to be made, where much loss is occasioned by defective castings, or where the iron will not flow well, or give sound and strong castings, the aluminum certainly in many cases allows better work to be done and stronger and sounder castings to be made, having a closer grain, and hence much easier tooled. The tendency of the aluminum is to change combined carbon to graphitic, and it lessens the tendency of the metal to chill. Aluminum in proportions of two per cent. and over, materially decreases the shrinkage of cast iron.

ALUMINUM IN WROUGHT IRON. The effect of aluminum in wrought iron is not very marked in the ordinary puddling process. It seems to add somewhat to the strength of the iron, but the amount is not of sufficient value to induce the general use of aluminum for this purpose. The peculiar property of aluminum in reducing the long range of temperature between that at which wrought iron first softens and that at which it becomes fluid, is taken advantage of in the well-known Mitis process for making "wrought iron castings." It is for this that aluminum is most used in wrought iron at present.

One per cent. of aluminum makes wrought iron more fluid at 2,200 degrees Fahrenheit (which is about the melting point of cast iron) than it would be without it at 3,500 degrees Fahrenheit.

In puddling iron an addition of 0.25 per cent. to the bath causes the charge to stiffen more quickly, and in the shingling process and in rolling the balls work much stiffer than usual. In one instance, where the ordinary iron averaged 22 tons tensile strength, with 12 per cent. elongation, the iron treated with aluminum showed over 30 tons tensile strength, with 22 per cent. elongation.

Digitized by Google

UNIV. OF CALIFORNIA

GAUGES.

As so many different gauges are in use in different countries, and even in different parts of the United States, and as no two gauges are exactly alike after being in use a few weeks (even if they are correct to start with), we advise all our customers, for the sake of clearness and accuracy, to give the thickness of sheets or diameter of wire in thousandths of an inch, or in millimetres, as they prefer. Micrometer gauges are now so common, that this is no longer a matter of difficulty.

To aid our customers, comprehensive tables are given in the following pages. First, of the correct sizes of the various gauges; second, of the weights of sheets to gauge sizes; and third, of the weights of sheets and wires both to English and metric measurements; and we would recommend these to the consideration of all parties who are contemplating the use of aluminum for various purposes. The difference in weight between aluminum and other metals is here clearly shown, and in many cases it will be found that this difference renders aluminum the cheapest metal, apart from the many other advantages obtained by its use.

The following rules may be used to advantage by all who have occasion to convert the metric into English measurement, or vice versa:—

Divide weight of square metre in kilogrammes by .309 and the quotient is the weight per square foot in ounces.

Multiply weight per square foot in ounces by .039 and the product is the weight per square metre in kilogrammes.

Divide weight per square foot in ounces by 25.2 and the quotient is the thickness in m.m.

Multiply thickness in m.m. by 25.2 and the product is the weight per square foot in ounces, or the thickness in 64ths of an inch.

Digitized by Google

COMPARISON OF WIRE AND SHEET-METAL GAUGES.

No. of Gauge.	Brown and Sharpe's. Inches.	Brown and Sharpe's. Nearest Millimeter Dimensions.	Birmingham. Wire or Stubs Gauge. Inches.	Birmingham. Sheet-metal Gauge. Inches.	Roebling's, also Washburn and Moen's. Inches.	Trenton Iron Company. Inches.	U. S. Legal Standard. Inches.	British Imperial and Legal Standard. Inches.	No. of Gauge.
7/0					.490		.50000	500	7/0
6/0					.460		.46875	464	6/0
5/0					.430	.450	.43750	.432	5/0
4/0	.46000	11.683	.454		.393	.400	.40625	.400	4/0
3/0	.40964	10.405	.425		.362	.360	.37500	.372	3/0
2/0	.36480	9.266	.380		.331	.330	.34375	.348	2/0
0	.32486	8.251	.340		.307	.305	.31250	.324	0
1	.28930	7.348	.300	.0085	.283	.285	.28125	.300	1
2	.25763	6.544	.284	.0095	.263	.265	.265625	.276	2
3	.22942	5.827	.259	.0105	.244	.245	.25000	.252	3
4	.20431	5.189	.238	.012	.225	.225	.234375	.232	4
5	.18194	4.621	.220	.014	.207	.205	.21875	.212	5
6	.16202	4.115	.203	.016	.192	.190	.203125	.192	6
7	.14428	3.665	.180	.019	.177	.175	.18750	.176	7
8	.12849	3.264	.165	.021	.162	.160	.171875	.160	8
9	.11442	2.906	.148	.023	.148	.145	.15625	.144	9
10	.10190	2.588	.134	.027	.135	.130	.140625	.128	10
11	.09074	2.305	.120	.031	.120	.1175	.12500	.116	11
12	.08081	2.053	.109	.035	.105	.105	.109375	.104	12
13	.07196	1.828	.095	.038	.092	.0925	.09375	.092	13
14	.06408	1.628	.083	.042	.080	.080	.078125	.080	14
15	.05707	1.449	.072	.047	.072	.070	.0703125	.072	15
16	.05082	1.290	.065	.051	.063	.061	.06250	.064	16
17	.04526	1.150	.058	.055	.054	.0525	.05625	.056	17
18	.04030	1.024	.049	.060	.047	.045	.05000	.048	18
19	.03589	.9116	.042	.063	.041	.040	.04375	.040	19
20	.03196	.8118	.035	.065	.035	.035	.03750	.036	20
21	.02846	.7229	.032	.068	.032	.031	.034375	.032	21
22	.02535	.6439	.028	.072	.028	.028	.03125	.028	22
23	.02257	.5733	.025	.077	.025	.025	.028125	.024	23
24	.02010	.5105	.022	.082	.023	.0225	.02500	.022	24
25	.01790	.4547	.020	.090	.020	.020	.021875	.020	25
26	.01594	.4049	.018	.100	.018	.018	.01875	.018	26
27	.01419	.3604	.016	.112	.017	.017	.0171875	.0164	27
28	.01264	.32106	.014	.124	.016	.016	.015625	.0148	28
29	.01126	.2860	.013	.136	.015	.015	.0140625	.0136	29
30	.01002	.2545	.012	.150	.014	.014	.01250	.0124	30
31	.00893	.2268	.010	.166	.0135	.013	.0109375	.0116	31
32	.00795	.2019	.009	.182	.013	.012	.01015625	.0108	32
33	.00708	.1798	.008	.200	.011	.011	.009375	.0100	33
34	.00630	.1600	.007	.216	.010	.010	.00859375	.0092	34
35	.00561	.1425	.005	.238	.0095	.0095	.0078125	.0084	35
36	.00500	.1270	.004	.250	.009	.009	.00703125	.0076	36
37	.00445	.1130		.270	.0085	.0085	.006640625	.0068	37
38	.00396	.1006		.278	.008	.008	.00625	.0060	38
39	.00353	.0897		.289	.0075	.0075		.0052	39
40	.00314	.0798		.300	.007	.007		.0048	40
41	.00280	.0711						.0044	41
42	.00249	.0632						.0040	42

Digitized by Google

MASTER MECHANICS' STANDARD GAUGE (Decimal.)

Also Adopted by the Association of American Steel Manufacturers, October 23, 1896.

Master Mechanics' Standard Decimal Gauge.	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Millimeters.	Weight Per Sq. Ft. in Lbs. Avoirdupois.		
			ALUMINUM, Basis 167.1114 Lbs. per Cu. Ft. or .097 Lb. per Cu. Inch.	Iron, Basis 480 Lbs. Per Cu. Ft. or 0.2778 Lb. Per Cu. Inch.	Steel, Basis 489.6 Lbs. Per Cu. Ft. or 0.2833 Lb. Per Cu. Inch.
0.002	1-500	0.0508001	.028	0.080	0.082
0.004	1-250	0.1016002	.056	0.160	0.163
0.006	3-500	0.1524003	.084	0.240	0.245
0.008	1-125	0.2032004	.111	0.320	0.326
0.010	1-100	0.2540005	.140	0.400	0.408
0.012	3-250	0.3048001	.168	0.480	0.490
0.014	7-500	0.3556007	.195	0.560	0.571
0.016	2-125 ($\frac{1}{64}$+)	0.4064008	.224	0.640	0.653
0.018	9-500	0.4572009	.251	0.721	0.734
0.020	1-50	0.5080010	.279	0.801	0.816
0.022	11-500	0.5588011	.307	0.881	0.897
0.025	1-40	0.63500125	.349	1.001	1.020
0.028	7-250	0.7112014	.391	1.121	1.142
0.032	4-125 ($\frac{1}{32}$+)	0.8128016	.447	1.281	1.305
0.036	9-250	0.9144018	.503	1.441	1.469
0.040	1-25	1.0160020	.559	1.601	1.632
0.045	9-200	1.14100225	.629	1.801	1.836
0.050	1-20	1.2700025	.699	2.002	2.040
0.055	11-200	1.39500275	.768	2.202	2.244
0.060	3-50 ($\frac{1}{16}$—)	1.5240030	.838	2.402	2.448
0.065	13-200	1.64900325	.908	2.602	2.652
0.070	7-100	1.7780025	.978	2.802	2.856
0.075	3-40	1.90300375	1.048	3.002	3.060
0.080	2-25	2.0320040	1.117	3.202	3.264
0.085	17-200	2.15700425	1.187	3.403	3.468
0.090	9-100	2.2820045	1.257	3.603	3.672
0.095	19-200	2.41100475	1.327	3.803	3.876
0.100	1-10	2.5400050	1.397	4.003	4.080
0.110	11-100	2.7940055	1.537	4.404	4.487
0.125	1-8	3.17500625	1.746	5.004	5.099
0.135	27-200	3.42700675	1.886	5.404	5.507
0.150	3-20	3.8100075	2.096	6.005	6.119
0.165	33-200	4.18900825	2.305	6.605	6.731
0.180	9-50	4.5720090	2 515	7.206	7.343
0.200	1-5	5.0800100	2.794	8.006	8.159
0.220	11-50	5.5880110	3.073	8.807	8.974
0.240	6-25	6.0960120	3.353	9.608	9.791
0.250	1-4	6.3500125	3.493	10.008	10.199

Digitized by Google

Weight of Aluminum, Wro't Iron, Steel, Copper and Brass Plates.

THICKNESS DETERMINED BY AMERICAN (BROWN & SHARPE) GAUGE.

Water at 62° Fahrenheit, 62,355 lbs. per cubic foot.

Rolled Wrought Iron	is	2.8724	times	heavier	than	Rolled Aluminum.
" Steel	"	2.9322	"	"	"	"
" Copper	"	3.3321	"	"	"	"
" Brass	"	3.1900	"	"	"	"

	Aluminum.	Wr't Iron.	Steel.	Copper.	Brass.
Specific Gravity Rolled Metal,	2.680	7.698	7.858	8.930	8.549
Weight per cu. ft. Rolled Metal,	167.111	480.000	490.000	556.830	533.073

No. of Gauge.	Size of each No.	WEIGHT OF PLATES PER SQUARE FOOT.				
		ALUMINUM.	WR'T IRON.	STEEL.	COPPER.	BRASS.
	Inch.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
0000	.46000	6.406	18.400	18.784	21.345	20.435
000	.40964	5.704	16.386	16.728	19.010	18.200
00	.36480	5.080	14.592	14.895	16.928	16.205
0	.32486	4.524	12.995	13.265	15.075	14.431
1	.28930	4.029	11.572	11.813	13.425	12.851
2	.25763	3.588	10.306	10.520	11.955	11.445
3	.22942	3.195	9.173	9.369	10.647	10.193
4	.20431	2.845	8.173	8.343	9.481	9.076
5	.18194	2.534	7.278	7.430	8.443	8.083
6	.16202	2.256	6.481	6.616	7.513	7.197
7	.14428	2.009	5.770	5.890	6.693	6.408
8	.12849	1.789	5.139	5.246	5.961	5.707
9	.11443	1.594	4.578	4.673	5.311	5.084
10	.10189	1.418	4.075	4.160	4.728	4.526
11	.090742	1.264	3.630	3.706	4.212	4.032
12	.080808	1.126	3.234	3.301	3.751	3.591
13	.071961	1.002	2.878	2.938	3.339	3.196
14	.064084	.8924	2.564	2.617	2.974	2.847
15	.057068	.7946	2.282	2.330	2.648	2.535
16	.050820	.7078	2.033	2.075	2.358	2.258
17	.045257	.6302	1.810	1.848	2.100	2.010
18	.040303	.5612	1.612	1.646	1.870	1.790
19	.035890	.4998	1.436	1.465	1.665	1.594
20	.031961	.4450	1.278	1.305	1.483	1.420
21	.028462	.3964	1.139	1.162	1.321	1.265
22	.025347	.3530	1.014	1.035	1.176	1.126
23	.022571	.3143	.9028	.9216	1.047	1.003
24	.020100	.2798	.8039	.8207	.9325	.8927
25	.017900	.2492	.7159	.7308	.8304	.7949
26	.015940	.2219	.6375	.6508	.7395	.7080
27	.014195	.1976	.5678	.5796	.6587	.6305
28	.012641	.1760	.5056	.5161	.5865	.5514
29	.011257	.1567	.4503	.4597	.5224	.5001
30	.010025	.1396	.4011	.4095	.4653	.4455
31	.008928	.1244	.3572	.3647	.4144	.3967
32	.007950	.1107	.3181	.3247	.3690	.3532
33	.007080	.09854	.2831	.2890	.3287	.3147
34	.006304	.08778	.2522	.2569	.2925	.2801
35	.005614	.07817	.2246	.2292	.2605	.2494
36	.005000	.06962	.2000	.2042	.2320	.2221
37	.004453	.06201	.1781	.1818	.2066	.1978
38	.003965	.05521	.1586	.1619	.1840	.1761
39	.003531	.04917	.1412	.1442	.1639	.1569
40	.003144	.04378	.1257	.1284	.1459	.1396

Digitized by Google

TABLE SHOWING WEIGHT IN POUNDS

OF

SHEET AND BAR ALUMINUM; ALSO, BRASS AND STEEL

Water at 62° = 62.355 lbs.

Specific Gravity of Rolled Aluminum, 2.68. Specific Gravity of Rolled Brass, 8.549. Specific Gravity of Rolled Steel, 7.858.

Aluminum taken as 1, Brass is 3.190 times heavier, Steel is 2.9322 times heavier.

Thickness or Diameter, in inches.		Sheets, per Square Foot.			Square Bars, One Foot Long.			Round Bars One Foot Long.		
Fraction.	Decimal.	Aluminum.	Brass.	Steel.	Aluminum.	Brass.	Steel.	Aluminum.	Brass.	Steel.
1-16	.0625	.869	2.77	2.52	.004	.014	.013	.003	.011	.010
1-8	.125	1.739	5.55	5.10	.018	.057	.053	.014	.047	.042
3-16	.1875	2.609	8.32	7.65	.041	.131	.119	.032	.102	.094
1-4	.2500	3.479	11.10	10.20	.072	.230	.212	.057	.182	.167
5-16	.3125	4.348	13.87	12.75	.114	.380	.333	.089	.284	.261
3-8	.3750	5.218	16.64	15.30	.163	.520	.478	.128	.408	.375
7-16	.4375	6.088	19.42	17.85	.222	.708	.651	.174	.555	.511
1-2	.5000	6.958	22.20	20.40	.290	.925	.850	.227	.724	.667
9-16	.5625	7.827	24.97	22.95	.367	1.171	1.076	.288	.919	.845
5-8	.6250	8.697	27.74	25.50	.453	1.445	1.328	.356	1.136	1.043
11-16	.6875	9.567	30.52	28.05	.548	1.748	1.608	.430	1.372	1.262
3-4	.7500	10.436	33.29	30.60	.652	2.080	1.913	.516	1.646	1.502
13-16	.8125	11.306	36.07	33.15	.766	2.445	2.245	.601	1.917	1.763
7-8	.8750	12.175	38.84	35.70	.888	2.833	2.603	.697	2.223	2.044
15-16	.9375	13.045	41.61	38.25	1.019	3.251	2.989	.800	2.552	2.347
1	1.0000	13.915	44.39	40.80	1.159	3.697	3.400	.911	2.906	2.670
1 1-16	1.0625	14.784	47.16	43.35	1.309	4.176	3.838	1.028	3.279	3.014
1 1-8	1.125	15.654	49.94	45.90	1.467	4.630	4.303	1.152	3.675	3.379
1 3-16	1.1875	16.524	52.71	48.45	1.635	5.216	4.795	1.284	4.096	3.766
1 1-4	1.2500	17.394	55.48	51.00	1.812	5.780	5.312	1.423	4.539	4.173
1 5-16	1.3125	18.263	58.26	53.55	1.997	6.370	5.857	1.569	5.003	4.600
1 3-8	1.3750	19.133	61.04	56.10	2.192	6.692	6.428	1.722	5.491	5.049
1 7-16	1.4375	20.002	63.81	58.65	2.396	7.644	7.026	1.882	6.002	5.518
1 1-2	1.5000	20.872	66.58	61.20	2.609	8.322	7.650	2.049	6.536	6.008
1 9-16	1.5625	21.741	69.35	63.75	2.831	9.030	8.301	2.223	7.091	6.520
1 5-8	1.6250	22.611	72.13	66.30	3.062	9.768	8.978	2.405	7.672	7.051
1 11-16	1.6875	23.481	74.90	68.85	3.302	10.53	9.682	2.593	8.271	7.604
1 3-4	1.7500	24.350	77.67	71.40	3.550	11.32	10.41	2.789	8.896	8.178
1 13-16	1.8125	25.250	80.54	73.95	3.810	12.15	11.17	2.992	9.544	8.773
1 7-8	1.8750	26.090	83.22	76.50	4.075	13.00	11.95	3.202	10.21	9.388
1 15-16	1.9375	26.960	86.00	79.05	4.352	13.88	12.76	3.417	10.90	10.02
2	2.0000	27.829	88.77	81.60	4.638	14.79	13.60	3.642	11.62	10.68

Digitized by Google

Relation of Aluminum to the Official Table Adopted by the Association of Copper Manufacturers of the United States, 1893.

ROLLED COPPER has a specific gravity of 8.93. One cubic foot weighs 558.125 pounds. One square foot of one inch thick weighs 46.51 pounds.

ROLLED ALUMINUM has a specific gravity of 2.68. One cubic foot weighs 167.1114 pounds. One square foot of one inch thick weighs 13.9259 pounds.

Stub's gauge (nearest) No.	Thickness in decimal parts of an inch.	Oz. per square foot of Copper.	Oz. per square foot of Aluminum of same thickness.	Sheets 14x48 weight in lbs. of Copper.	Sheets 14x48 weight in lbs. of Aluminum of same thickness.	Sheets 24x28 weight in lbs. of Copper.	Sheets 24x48 weight in lbs. of Aluminum of same thickness.	Sheets 30x60 weight in lbs. of Copper.	Sheets 30x60 weight in lbs. of Aluminum of same thickness.	Sheets 36x72 weight in lbs. of Copper.	Sheets 36x72 weight in lbs. of Aluminum in same thickness.	Sh'ts 48x72 w'ght in lbs. of Cop'r	Sheets 48x72 weight in lbs. of Aluminum of same thickness.
35	.00537	4	1.20	1.16	0.35	2	0.60	3.12	0.93	4.50	1.35	6	1.80
33	.00806	6	1.80	1.75	0.52	3	0.90	4.68	1.40	6.75	2.02	9	2.69
31	.0107	8	2.40	2.33	0.70	4	1.20	6.25	1.87	9.00	2.69	12	3.59
29	.0134	10	2.99	2.91	0.87	5	1.50	7.81	2.34	11.25	3.37	15	4.49
27	.0161	12	3.59	3.50	1.05	6	1.80	9.37	2.81	13.50	4.04	18	5.39
26	.0188	14	4.19	4.08	1.22	7	2.10	10.93	3.27	15.75	4.72	21	6.29
24	.0215	16	4.79	4.66	1.40	8	2.40	12.50	3.74	18.00	5.39	24	7.19
23	.0242	18	5.39	5.25	1.57	6	2.69	14.06	4.21	20.25	6.06	27	9.08
22	.0269	20	5.99	5.83	1.75	10	2.99	15.62	4.68	22.50	6.74	30	8.98
21	.0322	24	7.99	7.00	2.10	12	3.59	18.75	5.61	27.00	8.08	36	10.78
19	.0430	32	9.58	9.33	2.79	16	4.79	25.00	7.49	26.00	10.78	48	14.37
18	.0538	40	11.98	11.66	3.49	20	5.99	31.25	9.36	45.00	13.47	60	17.96
16	.0645	48	14.37	14.00	4.19	24	7.19	37.50	11.23	54.00	16.17	72	21.56
15	.0754	56	16.77	16.33	4.89	28	8.38	43.75	13.10	63.00	18.86	84	25.15
14	.0860	64	19.16	18.66	5.59	32	9.58	50.00	14.97	72.00	21.56	96	28.74
13	.095	70	20.96	....	....	35	10.48	55.00	16.47	79.00	23.65	105	31.44
12	.109	81	24.25	....	....	40½	12.13	63.00	18.85	91.00	27.25	122	36.53
11	.120	89	26.65	....	....	44½	13.32	70.00	20.96	100.00	29.94	234	40.12
10	.134	100	29.94	....	....	50	14.97	78.00	23.85	112.00	23.54	150	44.91
9	.148	110	32.94	....	....	55	16.47	86.00	25.75	124.00	37.13	165	49.40
8	.165	123	36.83	....	....	61	18.26	96.00	28.74	138.00	41.32	184	55.09
7	.180	134	40.12	....	....	67	20.06	105.00	31.44	151.00	45.21	201	60.18
6	.203	151	45.21	....	....	75½	22.61	118.00	35.33	170.00	50.90	227	67.97
5	.220	164	49.10	....	....	82	24.55	128.00	38.32	184.00	55.09	246	73.66
4	.238	177	53.00	....	....	88½	26.50	138.00	41.32	199.00	59.58	266	79.64
3	.259	193	57.79	....	....	96	28.74	151.00	45.21	217.00	64.98	289	86.53
2	.284	211	63.18	....	....	105½	31.59	165.00	49.40	238.00	71.27	317	84.92
1	.300	223	66.77	....	....	111½	33.39	174.00	52.10	251.00	75.16	335	100.31
0	.340	253	75.77	....	....	126½	37.88	198.00	59.29	285.00	85.34	380	113.78

One ounce per square foot aluminum sheet is 0.00449 inches thick and corresponds to about No. 37 B. & S. gauge.

Zinc Sheets of Standard Dimensions have the Following Weights:

.0311	inch	thick	weighs	10 oz.	to	the square	foot.
.0437	"	"	"	12 oz.	"	"	"
.0534	"	"	"	14 oz.	"	"	"
.0611	"	"	"	16 oz.	"	"	"
.0686	"	"	"	18 oz.	"	"	"
.0761	"	"	"	20 oz.	"	"	"

Digitized by Google

WEIGHT PER SQUARE FOOT

OF THE DIFFERENT DENOMINATIONS OF ALUMINUM AND TIN PLATES AND CORRESPONDING NUMBER OF THE PROPOSED NEW U. S. STANDARD GAUGE.

SPECIFIC GRAVITY ALUMINUM, 2.68.

Trade Designati'n of Gauge.	Fraction of a Pound Aluminum.	Ozs. Aluminum.	Fraction of a Pound Tin Plate.	Ozs. Tin Plate.	Proposed U. S. Standard Gauge. *	Nearest B. & S. Gauge. *	Thickness in Decimal parts of an Inch. *
IC.......	.171	2.73	.5	8.	30	28	.0125
IX	.213	3.41	.625	10.	28	26	.015625
IXX.....	.242	3.88	.711	11.37	26½	24	.018930
IXXX....	.273	4.37	.8	12.8	25½	24	.020300
IXXXX..	.307	4.91	.9	14.4	25	23	.021875
IXXXXX	.341	5.46	1.0	16.	24	22	.02500
DC......	.218	3.50	.64	10.25	28	26	.015025
DX......	.283	4.52	.83	13.25	25½	24	.020300
DXX....	.331	5.29	.97	15.5	24	22	.02500
DXXX...	.379	6.07	1.11	17.8	23	21	.028125
DXXXX.	.426	6.82	1.25	20.	22	20	.031250

* Thickness of black sheet before tinning.

The thickness of tin plate varies according to the coating of tin retained on the surface of the sheet. About two or three numbers of Brown & Sharpe gauge should be added to the above columns for comparing the thickness of aluminum with tinned sheets.

Digitized by Google

WEIGHT OF SHEET METALS.

AUTHORITY.—MECHANICAL ENGINEERS' REFERENCE BOOK BY NELSON FOLEY.

Thickness in Millimetres.	Kilogrammes per Square Metre.										
	Distilled Water.	Aluminum.	Delta Metal.	Brass.	Copper.	Iron and Alumin. Bronze.	Lead.	Manganese Bronze.	Steel.	Muntz Metal.	Zinc.
¼	.25	.6675	2.15	2.112	2.195	1.925	2.85	2.1	1.96	2.055	1.8
½	.5	1.335	4.3	4.225	4.39	3.85	5.7	4.2	3.92	4.11	3.6
¾	.75	2.002	6.45	6.337	6.585	5.775	8.55	6.3	5.88	6.165	5.4
1	1.	2.67	8.6	8.45	8.78	7.7	11.4	8.4	7.84	8.22	7.2
1¼	1.25	3.337	10.75	10.562	10.975	9.625	14.25	10.5	9.8	10.275	9.
1½	1.5	4.005	12.9	12.675	13.17	11.55	17.1	12.6	11.76	12.33	10.8
1¾	1.75	4.672	15.05	14.787	15.365	13.475	19.95	14.7	13.72	14.385	12.6
2	2.	5.34	17.2	16.9	17.56	15.4	22.8	16.8	15.68	16.44	14.4
2¼	2.25	6.007	19.35	19.012	19.755	17.325	25.65	18.9	17.64	18.495	16.2
2½	2.5	6.675	21.5	21.125	21.95	19.25	28.5	21.	19.6	20.55	18.
2¾	2.75	7.342	23.65	23.237	24.145	21.175	31.35	23.1	21.56	22.605	19.8
3	3.	8.01	25.8	25.35	26.34	23.1	34.2	25.2	23.52	24.66	21.6
3¼	3.25	8.677	27.95	27.462	28.535	25.025	37.05	27.3	25.48	26.715	23.4
3½	3.5	9.345	30.1	29.575	30.73	26.95	39.9	29.4	27.44	28.77	25.2
3¾	3.75	10.01	32.25	31.687	32.295	28.875	42.75	31.5	29.4	30.825	27.

Digitized by Google

WEIGHT OF SHEET METALS.—Continued.

Thickness in Millimetres.	Kilogrammes per Square Metre.										
	Distilled Water.	Aluminum.	Delta Metal.	Brass	Copper.	Iron and Alumin. Bronze.	Lead.	Manganese Bronze.	Steel.	Muntz Metal.	Zinc.
4	4.	10.68	34.4	38.8	35.12	30.8	45.6	33.6	31.36	32.88	28.8
4¼	4.25	11.347	36.55	35.912	37.315	32.725	48.45	35.7	33.32	34.935	30.6
4½	4.5	12.015	38.7	38.025	39.51	34.65	51.3	37.8	35.28	36.99	32.4
4¾	4.75	12.682	40.85	40.137	41.705	36.575	54.15	39.9	37.24	39.045	34.2
5	5.	13.35	43.	42.25	43.9	38.5	57.	42.	39.2	41.1	36.
5¼	5.25	14.017	45.15	44.362	46.095	40.425	59.85	44.1	41.16	43.155	37.8
5½	5.5	14.685	47.3	46.475	48.29	42.35	62.7	46.2	43.12	45.21	39.6
5¾	5.75	15.352	49.45	48.587	50.485	44.275	65.55	48.3	45.08	47.265	41.4
6	6.	16.02	51.6	50.7	52.68	46.2	68.4	50.4	47.04	49.32	43.2
6¼	6.25	16.687	53.75	52.812	54.875	48.125	71.25	52.5	49.	51.375	45.
6½	6.5	17.355	55.9	54.925	57.07	50.05	74.1	54.6	50.96	53.43	46.8
6¾	6.75	18.022	58.05	57.037	59.265	51.975	76.95	56.7	52.92	55.485	48.6
7	7.	18.69	60.2	59.15	61.46	53.9	79.8	58.8	54.88	57.54	50.4
7¼	7.25	19.357	62.35	61.26	63.655	55.825	82.65	60.9	56.84	59.595	52.2
7½	7.5	20.025	64.5	63.375	65.85	57.75	85.5	63.	58.8	61.65	54.
7¾	7.75	20.692	66.65	65.487	68.045	59.675	88.35	65.1	60.76	63.705	55.8

Digitized by Google

WEIGHT OF SHEET METALS.—Continued.

Thickness in Millimetres.	Kilogrammes per Square Metre.										
	Distilled Water.	Aluminum.	Delta Metal.	Brass.	Copper.	Iron and Alumin. Bronze.	Lead.	Manganese Bronze.	Steel.	Muntz Metal.	Zinc.
8	8.	21.36	68.8	67.6	70.24	61.6	91.2	67.2	62.72	65.76	57.6
8¼	8.25	22.027	70.95	69.712	72.435	63.525	94.05	69.3	64.68	67.815	59.4
8½	8.5	22.695	73.1	71.825	74.63	65.45	96.9	71.4	66.64	69.87	61.2
8¾	8.75	23.362	75.25	73.937	76.825	67.375	99.75	73.5	68.6	71.925	63.
9	9.	24.03	77.4	76.05	79.02	69.3	102.6	75.6	70.56	73.98	64.8
9¼	9.25	24.697	79.55	78.16	81.215	71.225	105.4	77.7	72.52	76.035	66.6
9½	9.5	25.365	81.7	80.275	83.41	73.15	108.3	79.8	74.48	78.09	68.4
9¾	9.75	26.032	83.85	82.387	85.605	75.075	111.1	81.9	76.44	80.145	70.2
10	10.	26.7	86.	84.5	87.8	77.	114.	84.	78.4	82.2	72.
10½	10.5	28.035	90.3	88.72	92.19	80.85	119.7	88.2	82.32	86.31	75.6
11	11.	29.37	94.6	92.95	96.58	84.7	125.4	92.4	86.24	90.42	79.2
11½	11.5	30.7	98.9	97.17	100.97	88.55	131.1	96.6	90.16	94.53	82.8
12	12.	32.04	103.2	101.4	105.36	92.4	136.8	100.8	94.08	98.64	86.4
12½	12.5	33.37	107.5	105.62	109.75	96.25	142.5	105.	98.	102.7	90.
13	13.	34.71	111.8	109.85	114.14	100.1	148.2	109.2	101.9	106.9	93.6
13½	13.5	36.04	116.1	114.07	118.53	103.95	153.9	113.4	105.8	111.	97.2

Digitized by Google

WEIGHT OF SHEET METALS.—Continued.

Thickness in Millimetres.	Kilogrammes per Square Metre.										
	Distilled Water.	Aluminum.	Delta Metal.	Brass.	Copper.	Iron and Alumin. Bronze.	Lead.	Manganese Bronze.	Steel.	Muntz Metal.	Zinc.
14	14.	37.38	120.4	118.3	122.92	107.8	159.6	117.6	109.8	115.1	100.8
14½	14.5	38.71	124.7	122.52	127.31	111.65	165.3	121.8	113.7	119.2	104.4
15	15.	40.05	129.	126.75	131.7	115.5	171.	126.	117.6	123.3	108.
15½	15.5	41.38	133.3	130.97	136.09	119.35	176.7	130.2	121.5	127.4	111.6
16	16.	42.72	137.6	135.2	140.48	123.2	182.4	134.4	125.4	131.5	115.2
16½	16.5	44.05	141.9	139.42	144.87	127.05	188.1	138.6	129.4	135.6	118.8
17	17.	45.39	146.2	143.65	149.26	130.9	193.8	142.8	133.3	139.7	122.4
17½	17.5	46.72	150.5	147.87	153.65	134.75	199.5	147.	137.2	143.8	126.
18	18.	48.06	154.8	152.1	158.04	138.6	205.2	151.2	141.1	148.	129.6
18½	18.5	49.39	159.1	156.32	162.43	142.45	210.9	155.4	145.	152.1	133.2
19	19.	50.73	163.4	160.55	166.82	146.3	216.6	159.6	149.	156.2	136.8
19½	19.5	52.06	167.7	164.77	171.21	150.15	222.3	163.8	152.9	160.3	140.4
20	20.	53.4	172.	169.	175.6	154.	228.	168.	156.8	164.4	144.
20½	20.5	54.73	176.3	173.22	179.99	157.85	233.7	172.2	160.7	168.5	147.6
21	21.	56.07	180.6	177.45	184.38	161.7	239.4	176.4	164.6	172.6	151.2
21½	21.5	57.4	184.9	181.67	188.77	165.55	245.1	180.6	168.6	176.7	154.8

Digitized by Google

WEIGHT OF SHEET METALS.—Continued.

Thickness in Millimetres.	Kilogrammes per Square Metre.										
	Distilled Water.	Aluminum.	Delta Metal.	Brass.	Copper.	Iron and Alumin. Bronze.	Lead.	Manganese Bronze.	Steel.	Muntz Metal.	Zinc.
22	22.	58.74	189.2	185.9	193.16	169.4	250.8	184.8	172.5	180.8	158.4
22½	22.5	60.07	193.5	190.12	197.55	173.25	256.5	189.	176.4	184.9	162.
23	23.	61.41	197.8	194.35	201.94	177.1	262.2	193.2	180.3	189.1	165.6
23½	23.5	62.74	202.1	198.57	206.33	180.95	267.9	197.4	184.2	193.2	169.2
24	24.	64.08	206.4	202.8	210.72	184.8	273.6	201.6	188.2	197.3	172.8
24½	24.5	65.41	210.7	207.02	215.11	188.65	279.3	205.8	192.1	201.4	176.4
25	25.	66.75	215.	211.25	219.5	192.5	285.	210.	196.	205.5	180.
25½	25.5	68.08	219.3	215.47	223.89	196.35	290.7	214.2	199.9	209.6	183.6
26	26.	69.42	223.6	219.7	228.28	200.2	296.4	218.4	203.8	213.7	187.2
26½	26.5	70.75	227.9	223.92	232.67	204.05	302.1	222.6	207.8	217.8	190.8
27	27.	72.09	232.2	228.15	237.06	207.9	307.8	226.8	211.7	221.9	194.4
27½	27.5	73.42	236.5	232.37	241.45	211.75	313.5	231.	215.6	226.	198.
28	28.	74.76	240.8	236.6	245.84	215.6	319.2	235.2	219.5	230.2	201.6
28½	28.5	76.09	245.1	240.82	250.23	219.45	324.9	239.4	223.4	234.3	205.2
29	29.	77.43	249.4	245.05	254.62	223.3	330.6	243.6	227.4	238.4	208.8
29½	29.5	78.76	253.7	249.27	259.01	227.15	336.3	247.8	231.3	242.5	212.4
30	30.	80.1	258.	253.5	263.4	231.	342.	252.	235.2	246.6	216.

Digitized by Google

IN POUNDS.

THE WEIGHT OF FLAT ROLLED BARS OF ALUMINUM,

PER LINEAL FOOT.

Specific Gravity 2.68 and at 62 degrees Fahr., Water taken as 62.355 Lbs. per cubic inch.

For Thickness from 3-16 in. to 2 in., and Widths from 1 in. to 12¾ in.

Thickness in Inches.	1″	1¼″	1½″	1¾″	2″	2¼″	2½″	2¾″	12″
3-16	.218	.272	.326	.379	.437	.491	.542	.597	2.609
1-4	.290	.362	.437	.508	.580	.651	.723	.798	3.479
5-16	.362	.454	.542	.634	.723	.815	.904	.996	4.348
3-8	.437	.542	.651	.761	.870	.979	1.088	1.197	5.218
7-16	.508	.634	.761	.887	1.016	1.143	1.269	1.395	6.088
1-2	.580	.723	.870	1.016	1.159	1.306	1.449	1.593	6.958
9-16	.655	.815	.979	1.143	1.306	1.466	1.630	1.794	7.827
5-8	.723	.904	1.088	1.269	1.449	1.630	1.811	1.992	8.697
11-16	.798	.996	1.197	1.395	1.593	1.794	1.992	2.193	9.567
3-4	.870	1.088	1.306	1.524	1.739	1.961	2.176	2.394	10.436
13-16	.941	1.177	1.412	1.651	1.882	2.118	2.353	2.592	11.306
7-8	1.016	1.269	1.521	1.773	2.029	2.282	2.538	2.790	12.175
15-16	1.088	1.361	1.630	1.903	2.176	2.449	2.718	2.991	13.045
1	1.159	1.449	1.739	2.029	2.319	2.609	2.899	3.189	13.915
1 1-16	1.231	1.541	1.848	2.155	2.462	2.773	3.080	3.387	14.784
1 1-8	1.306	1.630	1.958	2.285	2.609	2.936	3.264	3.588	15.654
1 3-16	1.378	1.722	2.067	2.411	2.756	3.100	3.445	3.789	16.524
1 1-4	1.449	1.811	2.176	2.538	2.899	3.264	3.625	3.987	17.393
1 5-16	1.521	1.903	2.282	2.664	3.046	3.424	3.806	4.185	18.263
1 3-8	1.593	1.992	2.394	2.790	3.189	3.588	3.987	4.383	19.133
1 7-16	1.668	2.084	2.503	2.919	3.336	3.752	4,168	4.584	20.002
1 1-2	1.739	2.176	2.609	3.045	3.479	3.915	4.349	4.785	20.872
1 9-16	1.814	2.265	2.718	3.172	3.625	4.076	4.530	4.983	21.741
1 5-8	1.882	2.353	2.827	3.298	3.769	4.239	4.710	5.181	22.611
1 11-16	1.958	2.445	2.936	3.424	3.912	4.403	4.891	5.382	23.481
1 3-4	2.029	2.538	3.045	3.551	4.059	4.570	5.075	5.580	24.350
1 13-16	2.101	2.626	3.151	3.680	4.205	4.727	5.252	5.781	25.250
1 7-8	2.176	2.718	3.264	3.806	4.349	4.891	5.437	5.979	26.090
1 15-16	2.248	2.810	3.370	3.392	4.495	5.058	5.621	6.180	26.960
2	2.319	2.899	3.479	4.059	4.638	5.218	5.798	6.378	27.829

Digitized by Google

IN POUNDS.

THE WEIGHT OF FLAT ROLLED BARS OF ALUMINUM,

PER LINEAL FOOT.

(CONTINUED.)

Thickness in Inches.	3″	3¼″	3½″	3¾″	4″	4¼″	4½″	4¾″	12″
3-16	.651	.706	.761	.815	.870	.924	.979	1.033	2.609
1-4	.870	.941	1.016	1.088	1.159	1.231	1.306	1.378	3.479
5-16	1.088	1.177	1.269	1.361	1.449	1.541	1.630	1.722	4.348
3-8	1.306	1.415	1.524	1.630	1.739	1.848	1.961	2.067	5.218
7-16	1.521	1.647	1.773	1.903	2.029	2.155	2.285	2.411	6.088
1-2	1.739	1.886	2.029	2.176	2.319	2.462	2.609	2.756	6.958
9-16	1.958	2.121	2.285	2.445	2.609	2.773	2.936	3.100	7.827
5-8	2.176	2.357	2.538	2.718	2.899	3.080	3.264	3.445	8.697
11-16	2.394	2.592	2.790	2.988	3.189	3.387	3.588	3.789	9.567
3-4	2.609	2.828	3.045	3.264	3.479	3.697	3.915	4.134	10.436
13-16	2.827	3.062	3.298	3.533	3.769	4.004	4.239	4.475	11.306
7-8	3.045	3.298	3.551	3.806	4.059	4.315	4.570	4.819	12.175
15-16	3.264	3.533	3.806	4.076	4.349	4.621	4.891	5.164	13.045
1	3.479	3.769	4.059	4.348	4.638	4.928	5.218	5.508	13.915
1 1-16	3.697	4.004	4.315	4.621	4.928	5.235	5.546	5.853	14.784
1 1-8	3.915	4.240	5.567	4.891	5.218	5.546	5.873	6.197	15.654
1 3-16	4.134	4.475	4.819	5.164	5.508	5.852	6.197	6.542	16.524
1 1-4	4.348	4.710	5.071	5.436	5.798	6.160	6.528	6.888	17.393
1 5-16	4.567	4.945	5.328	5.710	6.088	6.467	6.849	7.231	18.263
1 3-8	4.785	5.184	5.580	5.979	6.378	6.777	7.176	7.576	19.133
1 7-16	5.000	5.416	5.832	6.251	6.668	7.084	7.500	7.919	20.002
1 1-2	5.218	5.655	6.088	6.524	6.958	7.394	7.827	8.269	20.872
1 9-16	5.436	5.890	6.344	6.794	7.248	7.702	8.145	8.608	21.741
1 5-8	5.655	6.126	6.596	7.066	7.538	8.009	8.480	8.953	22.611
1 11-16	5.872	6.361	6.848	7.336	7.827	8.315	8.806	9.297	23.481
1 3-4	6.088	6.596	7.104	7.613	8.118	8.626	9.134	9.642	24.350
1 13-16	6.306	6.832	7.356	7.882	8.407	8.933	9.458	9.970	25.250
1 7-8	6.524	7.066	7.609	8.154	8.697	9.242	9.785	10.300	26.090
1 15-16	6.744	7.302	7.864	8.424	8.988	9.550	10.110	10.672	26.960
2	6.958	7.538	8.118	8.696	9.277	9.856	10.436	11.015	27.829

Digitized by Google

IN POUNDS.

THE WEIGHT OF FLAT ROLLED BARS OF ALUMINUM,

PER LINEAL FOOT.

(CONTINUED.)

Thickness in inches.	5″	5¼″	5½″	5¾″	6″	6¼″	6½″	6¾″	12″
3-16	1.088	1.143	1.197	1.252	1.306	1.361	1.415	1.466	2.609
1-4	1.449	1.521	1.593	1.668	1.739	1.811	1.886	1.958	3.479
5-16	1.811	1.903	1.992	2.084	2.176	2.265	2.357	2.445	4.348
3-8	2.176	2.282	2.394	2.503	2.609	2.722	2.828	2.936	5.218
7-16	2.538	2.664	2.790	2.919	3.045	3.168	3.298	3.424	6.088
1-2	2.899	3.045	3.189	3.332	3.479	3.626	3.769	3.915	6.958
9-16	3.264	3.424	3.588	3.752	3.915	4.076	4.240	4.403	7.827
5-8	3.625	3.806	3.987	4.168	4.348	4.529	4.710	4.891	8.697
11-16	3.987	4.185	4.383	4.587	4.785	4.983	5.184	5.382	9.567
3-4	4.349	4.567	4.785	5.007	5.218	5.433	5.655	5.873	10.436
13-16	4.710	4.945	5,181	5.416	5.655	5.890	6.126	6.361	11.306
7-8	5.075	5.328	5.580	5.836	6.088	6.344	6.596	6.849	12.175
15-16	5.437	5.709	5.979	6.251	6.524	6.794	7.066	7.336	13.045
1	5.798	6.088	6.378	6.668	6.958	7.248	7.538	7.827	13.915
1 1-16	6.159	6.466	6.777	7.084	7.394	7.701	8.009	8.318	14.784
1 1-8	6.528	6.848	7.176	7.500	7.827	8.152	8.483	8.805	15.654
1 3-16	6.886	7.230	7.576	7.919	8.264	8.605	8.950	9.293	16.524
1 1-4	7.248	7.613	7.975	8.335	8.697	9.059	9.419	9.784	17.393
1 5-16	7.613	7.992	8.369	8.751	9.134	9.516	9.893	10.27	18.263
1 3-8	7.974	8.369	8.768	9.168	9.567	9.965	10.36	10.76	19.133
1 7-16	8.335	8.751	9.168	9.584	10.00	10.42	10.83	11.25	20.002
1 1-2	8.696	9.134	9.567	10.00	10.44	10.87	11.31	11.74	20.872
1 9-16	9.062	9.513	9.965	10.42	10.87	11.32	11.77	12.23	21.741
1 5-8	9.423	9.894	10.355	10.84	11.31	11.78	12.25	12.72	22.611
1 11-16	9.784	10.273	10.760	11.25	11.74	12.23	12.72	13.21	23.481
1 3-4	10.147	10.655	11.162	11.67	12.17	12.68	13.19	13.70	24.350
1 13-16	10.508	11.033	11.558	12.08	12.61	13.14	13.66	14.19	25.250
1 7-8	10.869	11.416	11.958	12.50	13.04	13.59	14.13	14.67	26.090
1 15-16	11.233	11.796	12.356	12.92	13.43	14.04	14.60	15.16	26.960
2	11.595	12.176	12.756	13.33	13.91	14.49	15.07	15.65	27.829

Digitized by Google

IN POUNDS.

THE WEIGHT OF FLAT ROLLED BARS OF ALUMINUM,

PER LINEAL FOOT.

(CONTINUED.)

Thickness in inches.	7″	7¼″	7½″	7¾″	8″	8¼″	8½″	8¾″	12″
3-16	1.521	1.576	1.630	1.685	1.739	1.794	1.848	1.903	2.609
1-4	2.029	2.101	2.172	2.244	2.319	2.391	2.462	2.534	3.479
5-16	2.538	2.626	2.718	2.807	2.899	2.988	3.080	3.169	4.348
3-8	3.045	3.155	3.264	3.370	3.479	3.588	3.697	3.806	5.218
7-16	3.551	3.677	3.806	3.932	4.059	4.185	4.315	4.441	6.088
1-2	4.059	4.202	4.348	4.495	4.638	4.785	4.928	5.072	6.958
9-16	4.567	4.727	4.891	5.055	5.218	5.382	5.546	5.710	7.827
5-8	5.072	5.252	5.436	5.617	5.798	5.979	6.160	6.340	8.697
11-16	5.580	5.777	5.979	6.180	6.378	6.576	6.777	6.974	9.567
3-4	6.088	6.306	6.524	6.743	6.958	7.176	7.394	7.612	10.436
13-16	6.596	6.832	7.066	7.302	7.538	7.773	8.009	8.243	11.306
7-8	7.104	7.356	7.613	7.861	8.118	8.373	8.626	8.881	12.175
15-16	7.613	7.881	8.154	8.424	8.697	8.970	9.242	9.513	13.045
1	8.118	8.406	8.696	8.988	9.277	9.567	9.856	10.15	13.915
1 1-16	8.626	8.932	9.242	9.550	9.856	10.16	10.47	10.78	14.784
1 1-8	9.134	9.458	9.781	10.11	10.44	10.76	11.09	11.42	15.654
1 3-16	9.638	9.982	10.33	10.67	11.02	11.36	11.70	12.05	16.524
1 1-4	10.15	10.51	10.87	11.23	11.60	11.96	12.32	12.69	17.393
1 5-16	10.65	11.03	11.42	11.80	12.18	12.55	12.94	13.32	18.263
1 3-8	11.16	11.56	11.96	12.36	12.76	13.15	13.55	13.95	19.133
1 7-16	11.67	12.09	12.50	12.92	13.33	13.75	14.17	14.59	20.002
1 1-2	12.17	12.61	13.05	13.48	13.91	14.35	14.78	15.22	20.872
1 9-16	12.68	13.13	13.59	14.04	14.50	14.95	15.40	15.86	21.741
1 5-8	13.19	13.66	14.13	14.60	15.08	15.54	16.02	16.49	22.611
1 11-16	13.70	14.18	14.67	15.17	15.65	16.14	16.63	17.12	23.481
1 3-4	14.21	14.71	15.22	15.73	16.23	16.74	17.25	17.76	24.350
1 13-16	14.71	15.24	15.76	16.29	16.81	17.34	17.87	18.39	25.250
1 7-8	15.22	15.76	16.31	16.85	17.39	17.94	18.48	19.03	26.090
1 15-16	15.73	16.29	16.85	17.41	17.97	18.54	19.10	19.66	26.960
2	16.23	16.81	17.39	17.97	18.55	19.13	19.71	20.29	27.829

Digitized by Google

IN POUNDS.

THE WEIGHT OF FLAT ROLLED BARS OF ALUMINUM,

PER LINEAL FOOT.

(CONTINUED.)

Thickness in inches.	9″	9¼″	9½″	9¾″	10″	10¼″	10½″	10¾″	12″
3-16	1.957	2.012	2.067	2.121	2.176	2.230	2.282	2.340	2.609
1-4	2.609	2.681	2.756	2.827	2.899	2.971	3.045	3.117	3.479
5-16	3.264	3.353	3.445	3.533	3.625	3.714	3.806	3.895	4.348
3-8	3.915	4.025	4.134	4.243	4.349	4.458	4.567	4.676	5.218
7-16	4.567	4.693	4.819	4.949	5.075	5.201	5.328	5.454	6.088
1-2	5.218	5.365	5.508	5.655	5.798	5.941	6.088	6.234	6.958
9-16	5.873	6.034	6.197	6.361	6.528	6.688	6.848	7.012	7.827
5-8	6.528	6.702	6.888	7.066	7.248	7.428	7.613	7.793	8.697
11-16	7.176	7.373	7.576	7.773	7.974	8.172	8.369	8.571	9.567
3-4	7.827	8.046	8.269	8.479	8.696	8.915	9.134	9.351	10.436
13-16	8.480	8.714	8.953	9.184	9.423	9.659	9.894	10.13	11.306
7-8	9.134	9.385	9.642	9.893	10.15	10.40	10.65	10.91	12.175
15-16	9.785	10.06	10.30	10.60	10.87	11.14	11.42	11.69	13.045
1	10.44	10.73	11.01	11.31	11.60	11.88	12.18	12.46	13.915
1 1-16	11.09	11.39	11.70	12.01	12.32	12.63	12.93	13.24	14.784
1 1-8	11.74	12.07	12.39	12.72	13.04	13.37	13.70	14.02	15.654
1 3-16	12.39	12.74	13.08	13.43	13.77	14.12	14.46	14.80	16.524
1 1-4	13.05	13.41	13.77	14.13	14.50	14.86	15.22	15.58	17.393
1 5-16	13.70	14.08	14.46	14.84	15.22	15.60	15.98	16.36	18.263
1 3-8	14.35	14.75	15.15	15.54	15.94	16.34	16.74	17.14	19.133
1 7-16	15.01	15.42	15.84	16.25	16.67	17.09	17.50	17.92	20.002
1 1-2	15.65	16.09	16.52	16.96	17.39	17.83	18.26	18.70	20.872
1 9-16	16.31	16.76	17.22	17.67	18.12	18.57	19.02	19.48	21.741
1 5-8	16.96	17.43	17.90	18.37	18.84	19.31	19.78	20.26	22.611
1 11-16	17.61	18.10	18.59	19.08	19.57	19.82	20.55	21.03	23.481
1 3-4	18.27	18.77	19.28	19.78	20.29	20.80	21.31	21.82	24.350
1 13-16	18.92	19.44	19.96	20.49	21.01	21.54	22.07	22.59	25.250
1 7-8	19.57	20.11	20.65	21.20	21.74	22.29	22.83	23.37	26.090
1 15-16	20.22	20.78	21.34	21.91	22.47	23.03	23.59	24.16	26.960
2	20.87	21.45	22.03	22.61	23.19	23.77	24.35	24.93	278 29

Digitized by Google

IN POUNDS.

THE WEIGHT OF FLAT ROLLED BARS OF ALUMINUM,

PER LINEAL FOOT.

(CONTINUED.)

Thickness in Inches.	11″	11¼″	11½″	11¾″	12″	12¼″	12½″	12¾″
3-16	2.394	2.445	2.503	2.555	2.609	2.667	2.722	2.773
1-4	3.189	3.284	3.332	3.411	3.479	3.554	3.626	3.697
5-16	3.987	4.076	4.168	4.260	4.348	4.437	4.529	4.621
3-8	4.785	4.894	5.007	5.113	5.218	5.328	5.433	5.543
7-16	5.580	5.710	5.836	5.965	6.088	6.217	6.344	6.470
1-2	6.378	6.524	6.668	6.811	6.958	7.101	7.248	7.390
9-16	7.176	7.336	7.500	7.667	7.827	7.992	8.152	8.318
5-8	7.975	8.155	8.335	8.516	8.697	8.877	9.059	9.273
11-16	8.768	8.971	9.168	9.368	9.567	9.767	9.965	10.16
3-4	9.567	9.781	10.00	10.22	10.436	10.66	10.87	11.04
13-16	10.36	10.60	10.84	11.07	11.306	11.54	11.78	12.01
7-8	11.16	11.42	11.67	11.92	12.175	12.43	12.68	12.94
15-16	11.96	12.23	12.50	12.78	13.045	13.32	13.59	13.86
1	12.76	13.04	13.33	13.63	13.915	14.20	14.49	14.78
1 1-16	13.55	13.86	14.17	14.48	14.784	15.09	15.40	15.71
1 1-8	14.35	14.68	15.00	15.33	15.654	15.98	16.31	16.63
1 3-16	15.15	15.49	15.84	16.18	16.524	16.87	17.21	17.56
1 1-4	15.95	16.31	16.67	17.03	17.393	17.75	18.12	18.48
1 5-16	16.74	17.12	17.50	17.88	18.263	18.64	19.02	19.41
1 3-8	17.54	17.94	18.33	18.73	19.133	19.53	19.93	20.33
1 7-16	18.33	18.75	19.17	19.59	20.002	20.42	20.84	21.25
1 1-2	19.13	19.56	20.00	20.44	20.872	21.31	21.74	22.18
1 9-16	19.92	20.38	20.84	21.29	21.741	22.19	22.65	23.10
1 5-8	20.73	21.20	21.67	22.14	22.611	23.08	23.55	24.02
1 11-16	21.52	22.01	22.50	22.99	23.481	23.97	24.46	24.95
1 3-4	22.32	22.83	23.34	23.85	24.350	24.86	25.37	25.87
1 13-16	23.12	23.64	24.17	24.69	25.250	25.74	26.27	26.80
1 7-8	23.92	24.46	25.00	25.55	26.090	26.63	27.18	27.72
1 15-16	24.71	25.28	25.84	26.40	26.960	27.52	28.08	28.65
2	25.51	26.09	26.67	27.25	27.829	28.41	28.99	29.57

The weights for 12 in. width are repeated on each page to facilitate making the additions necessary to obtain the weights of plates wider than 12 in. Thus, to find the weight of 15½ in. x ⅞ in., add the weights to be found in the same line for 3½ x ⅞ and 12 x ⅞, 3.551 + 12.175 = 15.726 lbs.

Digitized by Google

WEIGHTS OF ALUMINUM BARS IN POUNDS; ALSO AREAS OF SQUARES AND ROUND BARS, AND CIRCUMFERENCES OF ROUND BARS.

Specific Gravity, 2.68 and at 62 deg. Fahr., Water taken as 62.355 lbs. per Cubic Inch.

Thickness or Diameter in inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Area of Square Bar in Sq. Inches.	Area of Round Bar in Sq. Inches.	Circumference of Round Bar in Inches.
0					
$\frac{1}{16}$	.0044	.0034	.0039	.0031	.1963
$\frac{1}{8}$	.018	.014	.0156	.0123	.3927
$\frac{3}{16}$	.041	.032	.0352	.0276	.5890
$\frac{1}{4}$	.072	.057	.0625	.0491	.7854
$\frac{5}{16}$	.114	.089	.0977	.0767	.9817
$\frac{3}{8}$	.163	.128	.1406	.1104	1.1781
$\frac{7}{16}$	.222	.174	.1914	.1503	1.3744
$\frac{1}{2}$	.290	.227	.2500	.1963	1.5708
$\frac{9}{16}$	.367	.288	.3164	.2485	1.7671
$\frac{5}{8}$	.453	.356	.3906	.3068	1.9635
$\frac{11}{16}$	.548	.430	.4727	.3712	2.1598
$\frac{3}{4}$	.652	.516	.5625	.4418	2.3562
$\frac{13}{16}$	.766	.601	.6602	.5185	2.5525
$\frac{7}{8}$	.888	.697	.7656	.6013	2.7489
$\frac{15}{16}$	1.019	.800	.8789	.6903	2.9452
1	1.159	.911	1.0000	.7854	3.1416
$1\frac{1}{16}$	1.309	1.028	1.1289	.8866	3.3379
$1\frac{1}{8}$	1.467	1.152	1.2656	.9940	3.5343
$1\frac{3}{16}$	1.635	1.284	1.4102	1.1075	3.7306
$1\frac{1}{4}$	1.812	1.423	1.5625	1.2272	3.9270
$1\frac{5}{16}$	1.997	1.569	1.7227	1.3530	4.1233
$1\frac{3}{8}$	2.192	1.722	1.8906	1.4849	4.3197
$1\frac{7}{16}$	2.396	1.882	2.0664	1.6230	4.5160
$1\frac{1}{2}$	2.609	2.049	2.2500	1.7671	4.7124
$1\frac{9}{16}$	2.831	2.223	2.4414	1.9175	4.9087
$1\frac{5}{8}$	3.062	2.405	2.6406	2.0739	5.1051
$1\frac{11}{16}$	3.302	2.593	2.8477	2.2365	5.3014
$1\frac{3}{4}$	3.550	2.789	3.0625	2.4053	5.4978
$1\frac{13}{16}$	3.810	2.992	3.2852	2.5802	5.6941
$1\frac{7}{8}$	4.075	3.202	3.5156	2.7612	5.8905
$1\frac{15}{16}$	4.352	3.417	3.7539	2.9483	6.0868

Digitized by Google

SQUARE AND ROUND BARS.

(CONTINUED.)

Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Area of Square Bar in. Sq. Inches.	Area of Round Bar in Sq. Inches.	Circumference of Round Bar in Inches.
2	4.638	3.642	4.0000	3.1416	6.2832
1/16	4.931	3.874	4.2539	3.3410	6.4795
1/8	5.235	4.113	4.5156	3.5466	6.6759
3/16	5.549	4.358	4.7852	3.7583	6.8722
1/4	5.872	4.611	5.0625	3.9761	7.0686
5/16	6.203	4.870	5.3477	4.2000	7.2649
3/8	6.541	5.140	5.6406	4.4301	7.4613
7/16	6.889	5.409	5.9414	4.6664	7.6576
1/2	7.248	5.692	6.2500	4.9087	7.8540
9/16	7.616	5.979	6.5664	5.1572	8.0503
5/8	7.990	6.275	6.8906	5.4119	8.2467
11/16	8.376	6.578	7.2227	5.6727	8.4430
3/4	8.526	6.889	7.5625	5.9396	8.6394
13/16	9.174	7.203	7.9102	6.2126	8.8357
7/8	9.584	7.528	8.2656	6.4918	9.0321
15/16	10.001	7.857	8.6289	6.7771	9.2284
3	10.435	8.195	9.0000	7.0686	9.4248
1/16	10.876	8.540	9.3789	7.3662	9.6211
1/8	11.323	8.894	9.7656	7.6699	9.8175
3/16	11.782	9.252	10.160	7.9798	10.014
1/4	12.250	9.618	10.563	8.2958	10.210
5/16	12.724	9.992	10.973	8.6179	10.407
3/8	13.208	10.374	11.391	8.9462	10.603
7/16	13.702	10.763	11.816	9.2806	10.799
1/2	14.205	11.155	12.250	9.6211	10.996
9/16	14.711	11.560	12.691	9.9678	11.192
5/8	15.238	11.967	13.141	10.321	11.388
11/16	15.769	12.382	13.598	10.680	11.585
3/4	16.308	12.810	14.063	11.045	11.781
13/16	16.855	13.235	14.535	11.416	11.977
7/8	17.410	13.676	15.016	11.793	12.174
15/16	17.976	14.119	15.504	12.177	12.370

Digitized by Google

Table of Dimensions and Weights of Aluminum and Copper Wire.

Specific Gravity of Aluminum taken as 2.68, water weighing 62.355 pounds per cubic foot. Specific Gravity of Copper, 8.93.

Am. Gauge, B. & S. No.	Diam. Mils.	Area.		Weight and Length.			
		Circular Mils. (d^2) 1 mil. = .001 inch.	Square Inch, (d^2 x .7854.)	Pounds per mile, Alum'n.	Pounds per mile, Copper.	Feet per Pound Aluminum.	Feet per pound Copper.
0000	460.000	211600.00	166190.	1018.30	3393.07	5.185	1.728
000	409.640	167805.00	131790.	807.52	2690.75	6.539	2.179
00	364.800	133079.40	104520.	640.36	2133.74	8.246	2.748
0	324.860	105534.00	82886.	507.83	1692.14	10.397	3.465
1	289.300	83694.20	65733.	402.81	1342.21	13.108	4.368
2	257.630	66373.00	52130.	319.44	1064.39	16.529	5.508
3	229.420	52634.00	41339.	253.55	843.96	20.846	6.946
4	204.310	41742.00	32784.	200.90	669.44	26.281	8.757
5	181.940	33102.00	25998.	159.30	530.79	33.146	11.044
6	162.020	26250.50	20617.	126.35	421.02	41.789	13.924
7	144.280	20816.00	16349.	100.21	333.93	52.687	17.556
8	128.490	16509.00	12966.	79.46	264.78	66.445	22.140
9	114.430	13094.00	10284.	62.99	209.90	83.822	27.931
10	101.890	10381.00	8153.2	49.95	166.49	105.68	35.215
11	90.742	8234.00	6467.0	39.63	132.04	133.24	44.3[illegible]8
12	80.808	6529.90	5128.6	31.43	104.71	168.01	55.983
13	71.961	5178.40	4067.1	24.92	83.02	211.86	70.595
14	64.084	4106.80	3146.9	19.76	65.83	267.17	89.0[illegible]2
15	57.068	3256.70	2557.8	15.67	52.22	336.93	112.2[illegible]
16	50.820	2582.90	2028.6	12.43	41.42	424.81	141.55
17	45.257	2048.20	1608.6	9.857	32.85	535.62	178.47
18	40.303	1624.30	1275.7	7.814	26.04	675.67	225.14
19	35.890	1288.10	1011.66	6.199	20.65	851.79	283.82
20	31.961	1021.50	802.28	4.916	16.38	1074.11	357.91
21	28.462	810.10	636.25	3.898	12.99	1354.65	451.38
22	25.347	642.70	504.78	3.091	10.30	1707.94	569.10
23	22.571	509.45	400.12	2.451	8.169	2153.78	717.66
24	20.100	404.01	317.31	1.944	6.478	2715.91	904.97
25	17.900	320.40	251.64	1.542	5.138	3424.66	1141.1
26	15.940	254.01	199.50	1.223	4.075	4317.78	1438.7
27	14.195	201.50	158.26	.9694	3.230	5446.63	1814.9
28	12.641	159.79	125.50	.7688	2.562	6868.13	2288.5
29	11.257	126.72	99.526	.6098	2.032	8698.03	2884.9
30	10.025	100.50	78.933	.4836	1.612	10917.0	3637.7
31	8.928	79.71	62.604	.3836	1.278	13762.8	4585.9
32	7.950	63.20	49.637	.3041	1.013	17361.1	5784.9
33	7.080	50.13	39.372	.2412	.8039	21886.7	7292.9
34	6.304	39.74	31.212	.1912	.6373	27609.1	9199.6
35	5.614	31.52	24.756	.1517	.5055	34807.3	11627.4
36	5.000	25.00	19.635	.1203	.4010	43878.9	14620.6
37	4.453	19.83	15.567	.0954	.3179	55340.4	18440.9
38	3.965	15.72	12.347	.0757	.2521	69783.7	23252.6
39	3.531	12.47	9.7939	.0600	.1999	88028.2	29331.9
40	3.144	9.89	7.7676	.0475	.1584	111099.0	37019.2

Digitized by Google

Weight of Aluminum, Wro't Iron, Steel, Copper and Brass Wire.

Diameters Determined by American (Brown & Sharpe) Gauge.

Water at 62° Fahrenheit, 62.355 lbs. per cubic foot.

Drawn Wrought Iron is 2.8724 times heavier than Drawn Aluminum.
" Steel " 2.9322 " " " " "
" Copper " 3.3321 " " " " "
" Brass " 3.1900 " " " " "

			Weight of Wire Per 1000 Lineal Ft.				
No. of Gauge.	Size of each No.	Ft. per lb. Aluminum.	Aluminum.	Wr't Iron.	Steel.	Copper.	Brass.
	Inch.	*Feet.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
0000	.46000	5.185	192.86	553.97	565.50	642.68	615.21
000	.40964	6.539	152.94	439.33	448.45	509.32	487.92
00	.36480	8.246	121.28	348.40	355.65	404.20	386.94
0	.32486	10.396	96.18	276.30	282.02	320.50	306.83
1	.28930	13.108	76.29	219.11	223.68	254.20	243.35
2	.25763	16.529	60.50	173.78	177.38	201.60	192.98
3	.22942	20.846	47.97	137.80	140.67	159.86	153.02
4	.20431	26.281	38.05	109.28	111.57	126.78	121.37
5	.18194	33.146	30.17	86.68	88.46	100.54	96.26
6	.16202	41.789	23.93	68.73	70.15	79.72	76.32
7	.14428	52.687	18.98	54.43	55.56	63.23	60.53
8	.12849	66.445	15.05	43.23	44.12	50.14	48.00
9	.11443	83.822	11.93	34.28	34.99	39.77	38.07
10	.10189	105.68	9.462	27.18	27.74	31.53	30.18
11	.090742	133.24	7.505	21.56	22.01	25.01	23.94
12	.080808	163.01	5.952	17.10	17.46	19.83	18.99
13	.071961	211.86	4.720	13.56	13.84	15.73	15.06
14	.064084	267.17	3.743	10.75	10.98	12.47	11.94
15	.057068	336.93	2.968	8.526	8.704	9.890	9.468
16	.050820	424.81	2.354	6.761	6.903	7.843	7.508
17	.045257	535.62	1.867	5.362	5.474	6.220	5.955
18	.040303	675.67	1.480	4.252	4.342	4.933	4.723
19	.035890	851.79	1.174	3.372	3.443	3.912	3.755
20	.031961	1074.11	.9310	2.672	2.730	3.102	2.970
21	.028462	1356.	.7382	2.121	2.165	2.460	2.355
22	.025347	1707.94	.5855	1.682	1.717	1.951	1.868
23	.022571	2153.78	.4643	1.333	1.361	1.547	1.481
24	.020100	2715.91	.3682	1.058	1.080	1.227	1.175
25	.017900	3424.66	.2920	.8388	.8563	.9731	.9316
26	.015940	4317.78	.2316	.6652	.6791	.7716	.7387
27	.014195	5446.63	.1836	.5276	.5385	.6120	.5858
28	.012641	6868.13	.1456	.4183	.4270	.4853	.4645
29	.011257	8657.5	.1155	.3317	.3386	.3849	.3683
30	.010025	10917.0	.0916	.2631	.2686	.3052	.2922
31	.008928	13762.8	.0727	.2087	.2130	.2421	.2318
32	.007950	17361.1	.0576	.1655	.1693	.1919	.1837
33	.007080	21886.7	.0457	.1312	.1340	.1522	.1457
34	.006304	27622.	.0362	.1040	.1062	.1207	.1155
35	.005614	34807.3	.0287	.0825	.0842	.0957	.0916
36	.005000	43878.9	.0228	.0655	.0668	.0759	.0727
37	.004453	55245.	.0181	.0519	.0530	.0602	.0577
38	.003965	69783.7	.0143	.0413	.0420	.0478	.0457
39	.003531	88028.2	.0114	.0326	.0333	.0379	.0363
40	.003144	110980.	.0090	.0259	.0264	.0300	.0287
Specific Gravity Wire............			2.680	7.698	7.858	8.930	8.549
Weight per cubic foot, Wire ...			167.111	480.000	490.000	556.830	533.073

Digitized by Google

TABLE OF RESISTANCES OF PURE ALUMINUM WIRE. *

Conductivity 62 in. the Matthiessen Standard Scale. Pure aluminum weighs 167.111 pounds per cubic foot.

Am. Gauge, B. & S. No.	Resistances at 70° F.				Log d^2.	Log R.
	R Ohms per 1000 Feet.	Ohms per mile.	Feet per Ohm.	Ohms per lb.		
0000	.07904	.41730	12652.	.00040985	5.325516	$\bar{1}$.897847
000	.09966	.52623	10034.	.00065102	5.224808	$\bar{1}$.998521
00	.12569	.66362	7956.	.0010364	5.124102	$\bar{1}$.099301
0	.15849	.83684	6310.	.0016479	5.023394	$\bar{1}$.200002
1	.19982	1.0552	5005.	.0026194	4.922688	$\bar{1}$.300639
2	.25200	1.3305	3968.	.0041656	4.821980	$\bar{1}$.401401
3	.31778	1.6779	3147.	.0066250	4.721274	$\bar{1}$.502127
4	.40067	2.1156	2496.	.010531	4.620566	$\bar{1}$.602787
5	.50526	2.6679	1975.	.016749	4.519860	$\bar{1}$.703515
6	.63720	3.3687	1569.	.026628	4.419152	$\bar{1}$.804276
7	.80350	4.2425	1245.	.042335	4.318446	$\bar{1}$.904986
8	1.0131	5.3498	987.0	.067318	4.217738	0.005652
9	1.2773	6.7442	783.0	.10710	4.117030	0.106293
10	1.6111	8.5065	620.8	.17028	4.016324	0.207122
11	2.0312	10.723	492.4	.27061	3.915616	0.307753
12	2.5615	13.525	390.5	.43040	3.814910	0.408494
13	3.2300	17.055	309.6	.68437	3.714202	0.509203
14	4.0724	21.502	245.6	1.0877	3.613496	0.609850
15	5.1354	27.114	194.8	1.7308	3.513788	0.710574
16	6.4755	34.190	154.4	2.7505	3.412082	0.811273
17	8.1670	43.124	122.5	4.3746	3.311374	0.912063
18	10.300	54.388	97.10	6.9590	3.210668	1.012837
19	12.985	68.564	77.05	11.070	3.109960	1.113442
20	16.381	86.500	61.06	17.595	3.009254	1.214340
21	20.649	109.02	48.43	27.971	2.908546	1.314899
22	26.025	137.42	38.44	44.450	2.807838	1.415391
23	32.830	173.35	30.45	70.700	2.707132	1.516271
24	41.400	218.60	24.16	112.43	2.606424	1.617000
25	52.200	275.61	19.16	178.78	2.505718	1.717671
26	65.856	347.70	15.19	284.36	2.405010	1.818595
27	83.010	438.32	12.05	452.62	2.304304	1.919130
28	104.67	552.64	9.55	718.95	2.203596	2.019822
29	132.00	697.01	7.58	1142.9	2.102890	2.120574
30	166.43	878.80	6.01	1817.2	2.002182	2.221232
31	209.85	1108.0	4.77	2888.0	1.901476	2.321909
32	264.68	1397.6	3.78	4595.5	1.800768	2.422721
33	333.68	1760.2	3.00	7302.0	1.700060	2.523330
34	420.87	2222.2	2.38	11627.	1.599354	2.624148
35	530.60	2801.8	1.88	18440.	1.498646	2.724767
36	669.00	3532.5	1.50	29352.	1.397940	2.825426
37	843.46	4453.0	1.19	46600.	1.297234	2.926064
38	1064.0	5618.0	.95	74240.	1.196526	3.026942
39	1341.2	7082.0	.75	118070.	1.095820	3.127494
40	1691.1	8930.0	.59	187700.	0.995112	3.228169

* Calculated on the basis of Dr. Matthiessen's standard, viz.: The resistance of a pure soft copper wire 1 meter long, having a weight of 1 gram = .141729 International Ohm at 0° C.

Digitized by Google

TABLE OF RESISTANCES OF PURE COPPER WIRE. *

Am. Gauge, B. & S. No.	Resistances at 70° F. R. Ohms 1000 Feet.	Ohms per mile.	Feet per Ohm.	Ohms per lb.	Log d^2.	Log R.
0000	.049286	.26050	20290.	.00007668	5.325516	$\bar{2}$.692724
000	.062148	.32813	16091.	.00012193	5.224808	$\bar{2}$.793427
00	.078363	.41378	12718.	.00019390	5.124102	$\bar{2}$.894111
0	.098816	.52174	10118.	.00030831	5.023394	$\bar{2}$.994827
1	.12459	.65780	8026.0	,00049015	4.922688	$\bar{1}$.095483
2	.15712	.82960	6364.2	.00077940	4.821980	$\bar{1}$.196231
3	.19824	1.0467	5044.5	.0012401	4.721274	$\bar{1}$.297191
4	.24982	1.3191	4002.8	.0019706	4.620566	$\bar{1}$.397627
5	.31504	1.6634	3174.2	.0031333	4.519860	$\bar{1}$.498366
6	.39725	2.0974	2517.3	.0049830	4.419152	$\bar{1}$.599064
7	.50099	2.6450	1996.2	.0079236	4.318446	$\bar{1}$.699829
8	.63176	3.3355	1582.8	.012599	4.217738	$\bar{1}$.800552
9	.79643	4.2052	1255.6	.020026	4.117030	$\bar{1}$.901148
10	1.0047	5.3042	995.42	.031880	4.016324	0.002036
11	1.2666	6.6878	789.58	.050650	3.915616	0.102639
12	1.5971	8.4325	626.16	.080520	3.814910	0.203332
13	2.0139	10.632	496.60	.12803	3.714202	0.304038
14	2.5396	13.408	393.78	.20364	3.613496	0.404765
15	3.1939	16.862	313.12	.32288	3.513788	0.504321
16	4.0378	21.319	247.68	.51473	3.412082	0.606145
17	5.0918	26.892	196.41	.81840	3.311374	0.706871
18	6.4201	33.901	155.77	1.3006	3.210668	0.807542
19	8.0860	42.692	123.67	2.0669	3.109960	0.907734
20	10.209	53.900	97.962	3.2903	3.009254	1.008983
21	12.873	67.970	77.685	5.2324	2.908456	1.109680
22	16.228	85.679	61.634	8.3140	2.807838	1.210265
23	20.471	108.08	48.851	13.232	2.707132	1.311139
24	25.813	136.28	38.742	21.035	2.606424	1.411838
25	32.550	171.86	30.713	33.340	2.505718	1.512551
26	41.058	216.78	24.353	53.226	2.405010	1.613398
27	51.758	273.55	19.320	84.578	2.304304	1.713977
28	65.265	344.57	15.321	134.34	2.203596	1.814680
29	82.292	434.48	12.151	213.80	2.102890	1.915358
30	103.77	547.90	9.6374	339.98	2.002182	2.016072
31	130.82	690.70	7.6439	540.40	1.901476	2.116674
32	165.01	871.22	6.0602	859.42	1.800768	2.217510
33	208.03	1098.3	4.8071	1365.8	1.700060	2.318126
34	262.42	1385.5	3.8105	2188.9	1.599354	2.418997
35	330.85	1746.8	3.0226	3456.0	1.498646	2.519631
36	417.16	2202.5	2.3972	5494.2	1.397940	2,620303
37	525.86	2776.7	1.9017	8732.3	1.297234	2.720870
38	663.36	3502.4	1.5075	13892.	1.196526	2.821749
39	836.23	4415.2	1.1958	22082.	1.095820	2.922326
40	1054.3	5566.4	.9484	35100.	0.995112	3.022964

*Calculated on the basis of Dr. Matthiessen's standard, viz.: The resistance of a pure soft copper wire 1 meter long, having a weight of 1 gram — ,141729 International Ohm at 0° C.

Digitized by Google

LIST OF STANDARD SIZES
OF
SEAMLESS DRAWN TUBING KEPT IN STOCK.

Inches Outside Diameter.	Thickness of Wall Stubs' Gauge.	Weights Per Foot in Pounds.	Inches Outside Diameter	Thickness of Wall Stubs' Gauge.	Weights Per Foot in Pounds.
1/4	24	.020	3/4	18	.130
1/4	22	.023	3/4	16	.170
1/4	20	.030	7/8	22	.090
1/4	18	.036	7/8	20	.110
5/16	24	.027	7/8	18	.160
5/16	22	.035	7/8	16	.200
5/16	20	.043	1	22	.100
5/16	18	.055	1	20	.130
3/8	24	.030	1	18	.180
3/8	22	.037	1	16	.230
3/8	20	.046	1 1/4	20	.160
3/8	18	.063	1 1/4	18	.230
7/16	24	.035	1 1/4	16	.300
7/16	22	.045	1 1/2	20	.190
7/16	20	.058	1 1/2	18	.270
7/16	18	.077	1 1/2	16	.360
1/2	24	.040	1 1/2	14	.450
1/2	22	.050	1 3/4	20	.230
1/2	20	.063	1 3/4	18	.320
1/2	18	.086	1 3/4	16	.420
1/2	16	.110	1 3/4	14	.530
5/8	20	.080	2	20	.260
5/8	18	.110	2	18	.360
5/8	16	.140	2	16	.480
3/4	22	.076	2	14	.610
3/4	20	.096	2	12	.790

Tu.es of any Size and Gauge Made to Order in Lots of over 50 Feet.
Specify whether to be Annealed for Bending.

Digitized by Google

ALUMINUM PIPE SIZES.

SEAMLESS DRAWN ALUMINUM TUBES MADE TO CORRESPOND WITH IRON TUBES AND TO FIT IRON TUBE FITTINGS.

LIST OF SIZES, LENGTHS, &c.

Same as Iron Size.	Outside Diameter.	Thickness Stubs' Gauge.	Weights per Foot.		
			Alum'um Lbs.	Brass Lbs.	Copper Lbs.
1/8	13/32	15	.089	.27	.29
1/4	17/32	15	.123	.37	.39
3/8	21/32	13	.199	.60	.64
1/2	13/16	12	.252	.76	.80
3/4	1 1/16	12	.404	1.22	1.28
1	1 5/16	11	.540	1.63	1.74
1 1/4	1 5/8	9	.835	2.52	2.65
1 1/2	1 7/8	9	.974	2.94	3.12
2	2 3/8	8	1.42	4.28	4.53
2 1/2	2 7/8	7	1.85	5.58	5.92
3	3 1/2	5	2.77	8.35	8.84
4	4 1/2	3	4.06	12.24	12.96

ALL TUBES

WARRANTED TO BE EQUAL IN QUALITY AND FINISH TO ANY MADE.

Digitized by Google

WEIGHTS IN POUNDS PER FOOT OF ALUMINUM

STUBS'

Nos. of Gauge. Thickness in thousandths of an Inch.	1 .300	2 .284	3 .259	4 .238	5 .220	6 .203	7 .180	8 .165	9 .148	10 .134	11 .120	12 .109
Diamet'r.												
¼ in.	....	....	....	....	....	....	....	....	....	....	....	....
⅜ "	....	....	....	....	....	....	....	....	....	....	.12	.11
½ "	....	....	....	....	....	....	....	.22	.20	.19	.18	.17
⅝ "	....	....	....	....	....	.33	.31	.30	.27	.25	.23	.22
¾ "	....	....	....	....	....	.43	.39	.37	.34	.32	.29	.27
⅞ "	....	....	.61	.58	.56	.52	.48	.45	.42	.38	.35	.32
1 "	.80	.78	.74	.70	.66	.62	.57	.53	.49	.45	.41	.37
1⅛ "	.94	.91	.86	.81	.76	.72	.65	.61	.56	.51	.46	.43
1¼ "	1.09	1.05	.98	.92	.87	.81	.74	.69	.63	.58	.52	.48
1⅜ "	1.23	1.18	1.11	1.03	.97	.91	.83	.77	.70	.64	.58	.53
1½ "	1.36	1.33	1.23	1.15	1.08	1.00	.92	.85	.77	.70	.64	.58
1⅝ "	1.52	1.45	1.36	1.26	1.18	1.11	.99	.93	.84	.77	.69	.63
1¾ "	1.66	1.59	1.48	1.38	1.29	1.20	1.09	1.01	.91	.83	.75	.69
1⅞ "	1.81	1.73	1.60	1.49	1.39	1.30	1.17	1.09	.98	.90	.81	.74
2 "	1.94	1.84	1.73	1.61	1.50	1.40	1.25	1.17	1.05	.96	.87	.79
2¼ "	2.23	2.13	1.97	1.77	1.71	1.59	1.43	1.32	1.20	1.09	.98	.90
2½ "	2.52	2.40	2.22	2.06	1.92	1.78	1.60	1.48	1.34	1.22	1.10	1.00
2¾ "	2.80	2.67	2.47	2.28	2.12	1.98	1.78	1.64	1.48	1.35	1.21	1.11
3 "	3.10	2.95	2.71	2.51	2.34	2.17	1.95	1.82	1.62	1.47	1.33	1.21
3¼ "	3.37	3.21	2.96	2.74	2.52	2.36	2.12	1.96	1.76	1.60	1.44	1.32
3½ "	3.65	3.48	3.21	2.97	2.76	2.56	2.29	2.11	1.90	1.73	1.56	1.42
3¾ "	3.97	3.81	3.47	3.19	2.96	2.75	2.46	2.27	2.05	1.86	1.67	1.52
4 "	4.24	4.03	3.70	3.42	3.18	2.90	2.64	2.43	2.19	1.99	1.79	1.63
4¼ "	4.51	4.30	3.71	3.65	3.39	3.14	2.81	2.59	2.33	2.12	1.90	1.73
4½ "	4.80	4.57	4.20	3.88	3.61	3.33	2.98	2.75	2.47	2.24	2.02	1.83
4¾ "	5.10	4.84	4.45	4.11	3.81	3.53	3.15	2.91	2.61	2.37	2.13	1.94
5 "	5.40	5.12	4.70	4.33	4.02	3.72	3.32	3.06	2.76	2.50	2.25	2.05
5¼ "	5.67	5.40	4.94	4.56	4.24	3.91	3.49	3.22	2.89	2.62	2.36	2.15
5½ "	5.96	5.66	5.19	4.79	4.44	4.07	3.67	3.38	3.04	2.76	2.48	2.26
5¾ "	6.26	5.93	5.44	5.02	4.65	4.30	3.84	3.54	3.18	2.89	2.59	2.36
6 "	6.53	6.20	5.68	5.24	4.86	4.49	4.01	3.70	3.32	3.01	2.71	2.47

Digitized by Google

'UBING OUTSIDE MEASUREMENT.

IAUGE.

13	14	15	16	17	18	19	20	21	22	23	24	Nos. of Gauge.
095	.083	.072	.065	.058	.049	.042	.035	.032	.028	.025	.022	Thickness in thousandths of an Inch.
												Diamet'r.
.060	.053	.050	.047	.044	.036	.033	.030	.027	.025	.023	.020	¼ in.
.100	.093	.083	.076	.069	.063	.053	.046	.043	.037	.033	.030	⅜ "
.147	.133	.120	.110	.100	.086	.073	.063	.056	.050	.046	.040	½ "
.190	.170	.150	.140	.130	.110	.093	.080	.073	.063	.056	.050	⅝ "
.240	.210	.190	.170	.150	.130	.110	.096	.090	.076	.070	.060	¾ "
.290	.250	.220	.200	.180	.160	.130	.110	.100	.090	.083	.073	⅞ "
.330	.290	.260	.230	.210	.180	.160	.130	.12	.10	.093	.083	1 "
.38	.33	.29	.27	.24	.20	.18	.15	.14	.12	.11	.093	1⅛ "
.41	.37	.33	.30	.27	.23	.20	.16	.15	.13	.12	.10	1¼ "
.46	.41	.36	.33	.29	.25	.22	.18	.17	.15	.13	.11	1⅜ "
.51	.45	.39	.36	.32	.27	.24	.19	.18	.16	.14	.12	1½ "
.56	.49	.43	.39	.35	.29	.26	.21	.19	.17	.15	.13	1⅝ "
.60	.53	.47	.42	.38	.32	.27	.23	.21	.18	.16	.14	1¾ "
.65	.57	.50	.45	.41	.34	.29	.24	.23	.20	.18	.15	1⅞ "
.70	.61	.53	.48	.43	.36	.31	.26	.24	.21	.19	.16	2 "
.79	.69	.60	.54	.49	.41	.36	.30	.27	.24	.21	.18	2¼ "
.88	.77	.69	.61	.54	.46	.39	.33	.30	.26	.24	.21	2½ "
.97	.85	.74	.67	.60	.51	.43	.36	.33	.29	.26	.23	2¾ "
1.07	.93	.81	.73	.65	.55	.48	.40	.36	.32	.28	.25	3 "
1.15	1.01	.88	.80	.71	.60	.52	.43	.39	.34	.31	.27	3¼ "
1.24	1.09	.95	.86	.77	.65	.56	.46	.42	.37	.33	.29	3½ "
1.34	1.17	1.02	.92	.82	.70	.60	.50	.46	.40	.36	.31	3¾ "
1.43	1.25	1.09	.98	.88	.74	.64	.53	.49	.42	.38	.33	4 "
1.52	1.33	1.16	1.05	.93	.79	.68	.56	.52	.45	.40	.36	4¼ "
.61	1.41	1.23	1.11	.99	.84	.72	.60	.55	.48	.43	.38	4½ "
.70	1.49	1.30	1.18	1.05	.88	.76	.63	.58	.51	.45	.40	4¾ "
.79	1.57	1.36	1.23	1.07	.93	.80	.67	.61	.53	.48	.42	5 "
.88	1.65	1.43	1.30	1.16	.98	.84	.70	.64	.56	.50	.44	5¼ "
.98	1.73	1.50	1.36	1.21	1.03	.88	.73	.67	.59	.52	.46	5½ "
.07	1.81	1.57	1.42	1.27	1.07	.92	.77	.70	.61	.55	.48	5¾ "
.16	1.89	1.64	1.48	1.33	1.12	.96	.80	.73	.64	.57	.50	6 "

Digitized by Google

SAFE PRESSURES ON ALUMINUM TUBING IN POUNDS PER SQUARE INCH.

According to the formula that the Tension per linear inch is equivalent to the Pressure per square inch, multiplied by the interior radius of the Tube, and to get the thickness of the Tube, divide by the Unit Stress per square inch.

Outside Dia. in inch.	Thickness of Wall, 1000ths of an inch.	No. Stubs Gauge.	Allowable Unit Stress in Pounds per Square Inch. 5000 lbs.	6000 lbs.	7000 lbs.	8000 lbs.	9000 lbs.	10000 lbs.
¼	.049	18	1960	2352	2744	3136	3528	3920
...	.035	20	1400	1680	1960	2240	2520	2800
...	.028	22	1120	1344	1568	1792	2016	2240
...	.022	24	880	1056	1232	1408	1584	1760
5-16	.049	18	1568	1882	2195	2508	2822	3136
...	.035	20	1120	1344	1568	1792	2016	2240
...	.028	22	896	1075	1254	1433	1613	1792
...	.022	24	704	845	986	1126	1267	1408
⅜	.049	18	1307	1568	1829	2090	2352	2613
...	.035	20	933	1120	1306	1493	1680	1866
...	.028	22	747	896	1045	1195	1344	1493
...	.022	24	587	704	821	939	1056	1173
7-16	.049	18	1120	1344	1568	1792	2016	2240
...	.035	20	800	960	1120	1280	1440	1600
...	.028	22	640	768	896	1024	1152	1280
...	.022	24	503	603	704	804	905	1005
½	.065	16	1300	1560	1820	2080	2340	2600
...	.049	18	980	1176	1372	1568	1764	1960
...	.035	20	700	840	980	1120	1260	1400
...	.028	22	560	672	784	896	1008	1120
...	.022	24	440	528	616	704	792	880
⅝	.065	16	1040	1248	1456	1664	1872	2080
...	.049	18	784	941	1098	1254	1411	1568
...	.035	20	560	672	784	896	1008	1120
...	.028	22	448	538	627	717	806	896
¾	.065	16	867	1040	1213	1387	1560	1733
...	.049	18	653	784	915	1045	1176	1306
...	.035	20	467	560	653	747	940	933
...	.028	22	373	448	523	597	672	746
⅞	.065	16	743	891	1040	1188	1337	1485
...	.049	18	560	672	784	896	1008	1120
...	.035	20	400	480	560	640	720	800
...	.028	22	320	384	448	512	576	640
1	.065	16	650	780	910	1040	1170	1300
...	.049	28	490	588	686	784	882	980
...	.035	20	350	420	490	560	630	700
...	.028	22	280	336	392	448	504	560
1¼	.083	14	664	797	930	1062	1195	1328
...	.062	16	520	624	728	832	936	1040
...	.049	18	392	470	549	627	706	784
...	.035	20	280	336	392	448	504	560

Digitized by Google

Safe Pressures on Aluminum Tubing in Pounds per Square Inch.—Continued.

Outside Diam. in inch.	Thickness of Wall, 1000ths of an inch.	No. Stubs Gauge.	Allowable Unit Stress in Pounds per Square Inch.					
			5000 lbs.	6000 lbs.	7000 lbs.	8000 lbs.	9000 lbs.	10000 lbs.
1½	.083	14	553	664	775	885	996	1106
...	.065	16	433	520	606	693	779	866
...	.049	18	327	392	457	523	588	653
...	.035	20	233	280	327	373	420	466
1¾	.083	14	474	569	664	759	854	949
...	.065	16	372	446	520	594	669	743
...	.049	18	280	336	392	448	504	560
...	.035	20	200	240	280	320	360	400
2	.109	12	545	654	763	872	981	1090
...	.083	14	415	498	581	664	747	830
...	.065	16	325	390	455	520	585	650
...	.049	18	245	294	343	592	441	490
...	.035	20	175	210	245	280	315	350
2¼	.109	12	485	581	678	775	872	969
...	.083	14	313	376	439	501	564	627
...	.065	16	289	347	404	462	520	578
2½	.109	12	438	526	613	701	788	876
...	.083	14	333	399	466	532	599	665
...	.065	16	260	312	364	416	468	520
2¾	.109	12	396	476	555	634	714	793
...	.083	14	302	362	423	483	543	604
...	.065	16	236	284	331	378	426	473
3	.134	10	447	536	625	715	804	893
...	.109	12	363	436	509	581	654	727
...	.083	14	277	332	387	443	498	553
3¼	.134	10	412	495	577	660	742	825
...	.109	12	335	403	470	537	604	671
...	.083	14	255	307	358	409	460	511
3½	.134	10	383	459	536	613	689	766
...	.109	12	311	374	436	478	561	623
...	.083	14	237	285	352	379	427	474
3¾	.134	10	357	429	500	572	643	715
...	.109	12	291	349	407	465	524	582
...	.083	14	221	266	310	354	399	443
4	.165	10	413	495	578	660	743	825
...	.134	12	335	402	469	536	603	670
...	.109	14	273	327	382	436	491	545
4¼	.165	10	388	466	543	621	699	776
...	.134	12	315	378	442	505	568	631
...	.109	14	257	308	359	410	462	513
4½	.165	10	367	440	513	587	660	733
...	.134	12	298	357	417	477	536	596
...	.109	14	242	291	339	387	436	484
4¾	.165	10	347	417	486	556	625	695
...	.134	12	282	339	395	451	508	564
...	.109	14	229	275	321	367	412	459
5	.165	10	330	396	462	528	594	660
...	.134	12	268	322	375	429	482	536
...	.109	14	218	262	305	349	392	436
5¼	.165	10	314	377	440	503	566	629
...	.134	12	255	306	357	409	460	510
...	.109	14	208	249	291	332	374	415

Digitized by Google

Safe Pressures on Aluminum Tubing in Pounds per Square Inch.—Continued.

Outside Diam. in inch.	Thickness of Wall, 1000ths of an inch.	No. Stubs Gauge.	Allowable Unit Stress in Pounds per Square Inch. 5000 lbs.	6000 lbs.	7000 lbs.	8000 lbs.	9000 lbs.	10000 lbs.
5½	.165	10	300	360	420	480	540	600
...	.134	12	244	292	341	390	438	487
...	.109	14	198	238	277	317	357	396
5¾	.165	10	287	344	402	459	517	574
...	.134	12	233	280	326	373	419	466
...	.109	14	190	227	265	303	341	379
6	.165	10	275	330	385	440	495	550
...	.134	12	223	268	313	357	402	447
...	.109	14	182	218	254	291	337	363
6½	.250	10	385	462	538	615	692	769
...	.1875	12	288	346	404	462	519	577
...	.175	14	192	231	269	308	346	385
7	.250	2–3	357	429	500	571	643	714
...	.1875	6–7	268	321	375	429	482	536
....	.175	10–11	179	214	250	286	321	357
7½	.250	2–3	333	400	467	543	600	667
...	.1875	6–7	250	300	350	400	450	500
...	.125	10–11	167	200	233	267	300	333
8	.250	2–3	313	375	438	500	563	625
...	.1875	6–7	234	281	328	375	422	469
...	.125	10–11	156	187	219	250	281	313
8½	.250	2–3	294	353	412	471	529	588
...	.1875	6–7	221	265	309	353	397	441
...	.125	10–11	147	176	206	235	265	294
9	.250	2–3	278	333	389	445	500	556
...	.1875	6–7	208	250	292	333	375	417
...	.125	10–11	139	167	194	222	250	278
10	.250	2–3	250	300	350	400	450	500
...	.1875	6–7	188	225	263	290	338	375
...	.125	10–11	125	150	175	200	225	250
11	.375	00–0	341	409	477	546	614	682
...	.250	2–3	228	273	319	365	410	456
...	.1875	6–7	170	205	239	273	307	341
...	.125	10–11	114	136	159	182	204	227
12	.500	ab0000	417	500	583	667	750	833
...	.375	00–0	313	375	438	500	563	625
...	.250	2–3	208	250	292	333	375	417
...	.125	10–11	104	125	146	167	187	208

The above allowable unit strains are based on a factor of safety of about four, and may be used as follows for the different alloys, when the temperature is not above 100° Centigrade; when the temperature is above 100° Centigrade, the allowable unit stresses should be divided by two, and aluminum should not be subject to strains at temperatures above 200° Centigrade.

Pure Aluminum (cast).........................5000 lbs. per sq. inch.
Special Casting Alloy (cast)..................5000 to 6000 lbs. per sq. inch.
Nickel Casting Alloy (cast) ....6000 to 8000 lbs. " "
Pure Alumi'um Tubing (made from sheet) 6000 to 8000 lbs. " "
Nickel " " " " " 8000 to 10,000 lbs. " "

For Riveted Joints: Single riveted 60 per cent. of the allowable unit stress as given above for the efficiency of the joint. For double riveted joints, 75 per cent. of the allowable stresses given above.

Digitized by Google

RIVETS AND BURRS. All sizes and styles of rivets and burrs will be made as desired. On account, however, of the expense and inconvenience of specially making small lots of rivets, The Pittsburgh Reduction Company carry in stock a large assortment of rivets. Orders for rivets of a size or style not carried in stock, will not be taken for lots of less than five pounds.

The Pittsburgh Reduction Company carry in stock, aluminum rivets of the same size and shape as iron "tinners" or "pound" rivets, as follows:—8 oz., 10 oz., 12 oz., 14 oz., 1 lb., 1¼ lb., 1½ lb., 1¾ lb., 2 lb., 2½ lb., 3 lb., 3½ lb., 4 lb., 5 lb., 6 lb., 7 lb., 8 lb., 9 lb., 10 lb., 12 lb., 14 lb. and 16 lb.

The following is the list of round head and flat head rivets (other than the pound rivets) kept in stock:

ROUND HEAD RIVETS KEPT IN STOCK.

(STUB'S GAUGE THE STANDARD.)

5/8	in. diameter,	1½	in. long.	11/32	in. diameter,	7/8	in. long.
5/8	" "	1	"	11/32	" "	11/16	"
5/8	" "	¾	"	11/32	" "	9/16	"
9/16	" "	1½	"	5/16	" "	1	"
9/16	" "	1	"	5/16	" "	¾	"
9/16	" "	¾	"	5/16	" "	5/8	"
½	" "	1½	"	5/16	" "	½	"
½	" "	1¼	"	5/16	" "	7/16	"
½	" "	1	"	No. 1,	"	11/16	"
½	" "	7/8	"	" 1,	"	9/16	"
½	" "	¾	"	" 1,	"	15/32	"
½	" "	5/8	"	" 2,	"	5/8	"
7/16	" "	1	"	" 2,	"	½	"
7/16	" "	½	"	" 2,	"	7/16	"
3/8	" "	1	"	" 3,	"	9/16	"
3/8	" "	5/8	"	" 3,	"	15/32	"
3/8	" "	½	"	" 3,	"	13/32	"
¼	" "	1	"				
¼	" "	¾	"				

Digitized by Google

RIVETS AND BURRS.—Continued.

1/4 in.	diameter,	5/8 in.	long	No. 9,	diameter,	1/4 in.	long
1/4 "	"	1/2	"	" 9,	"	3/16	"
1/4 "	"	7/16	"	" 10,	"	1/2	"
1/4 "	"	3/8	"	" 10,	"	13/32	"
1/4 "	"	5/16	"	" 10,	"	11/32	"
No. 4,	"	9/16	"	" 10,	"	9/32	"
" 4,	"	15/32	"	" 10,	"	3/16	"
" 4,	"	13/32	"	1/8 in.	"	1	"
" 5,	"	1/2	"	1/8 "	"	7/8	"
" 5,	"	7/16	"	1/8 "	"	3/4	"
" 5,	"	3/8	"	1/8 "	"	5/8	"
" 5,	"	5/16	"	1/8 "	"	1/2	"
" 6,	"	15/32	"	1/8 "	"	7/16	"
" 6,	"	13/32	"	1/8 "	"	3/8	"
" 6,	"	11/32	"	1/8 "	"	5/16	"
3/16 in.	"	1	"	1/8 "	"	1/4	"
3/16 "	"	7/8	"	1/8 "	"	3/16	"
3/16 "	"	3/4	"	1/8 "	"	1/8	"
3/16 "	"	5/8	"	No. 12,	"	11/32	"
3/16 "	"	1/2	"	" 12,	"	9/32	"
3/16 "	"	7/16	"	" 12,	"	7/32	"
3/16 "	"	3/8	"	" 12,	"	3/16	"
3/16 "	"	5/16	"	" 12,	"	5/32	"
3/16 "	"	1/4	"	" 13,	"	5/16	"
No. 7,	"	15/32	"	" 13,	"	1/4	"
" 7,	"	13/32	"	" 13,	"	3/16	"
" 7,	"	11/32	"	" 13,	"	1/8	"
" 8,	"	1	"	" 14,	"	1/4	"
" 8,	"	7/8	"	" 14,	"	3/16	"
" 8,	"	3/4	"	" 14,	"	1/8	"
" 8,	"	5/8	"	" 14,	"	3/32	"
" 8,	"	1/2	"	" 15,	"	7/32	"
" 8,	"	7/16	"	" 15,	"	5/32	"
" 8,	"	3/8	"	" 15,	"	3/32	"
" 8,	"	5/16	"	1/16 in.	"	1/4	"
" 9,	"	3/8	"	1/16 "	"	3/16	"
" 9,	"	5/16	"	1/16 "	"	1/8	"
				1/16 "	"	1/16	"

FLAT HEAD RIVETS KEPT IN STOCK.

(STUB'S GAUGE THE STANDARD.)

$\frac{3}{16}$ in.	diameter,	$\frac{13}{32}$	in. long.	No. 12,	diameter,	$\frac{5}{16}$	in. long.
$\frac{3}{16}$ "	"	$\frac{11}{32}$	"	" 12,	"	$\frac{1}{4}$	"
$\frac{3}{16}$ "	"	$\frac{9}{32}$	"	" 13,	"	$\frac{9}{32}$	"
No. 7,	"	$\frac{5}{16}$	"	" 13,	"	$\frac{7}{32}$	"
" 8,	"	$\frac{13}{32}$	"	" 13,	"	$\frac{3}{16}$	"
" 8,	"	$\frac{9}{32}$	"	" 14,	"	$\frac{7}{32}$	"
" 9,	"	$\frac{7}{32}$	"	" 14,	"	$\frac{5}{32}$	"
" 10,	"	$\frac{5}{16}$	"	" 15,	"	$\frac{3}{16}$	"
" 10,	"	$\frac{7}{32}$	"	" 15,	"	$\frac{1}{8}$	"
$\frac{1}{8}$ in.	"	$\frac{5}{16}$	"	$\frac{1}{16}$ in.	"	$\frac{5}{32}$	"
$\frac{1}{8}$ "	"	$\frac{1}{4}$	"	$\frac{1}{16}$ "	"	$\frac{3}{32}$	"
$\frac{1}{8}$ "	"	$\frac{3}{16}$	"				

ALUMINUM ANGLES.

The ratio of specific gravity of rolled steel and rolled aluminum of average composition, in bars and angles, is $\frac{7.87}{2.72}=2.894$.

The thickness of an aluminum angle in thirty-seconds of an inch, is equal to the weight per running foot multiplied by 2.894 and the product divided by the sum of the sides of the angle.

Digitized by Google

ALUMINUM ANGLES.

Weights per foot corresponding to thickness varying by $\frac{1}{16}''$.

One Cubic Foot weighing 172 lbs. Nickel Alloy.

Size Inches.	$\frac{1}{8}''$	$\frac{3}{16}''$	$\frac{1}{4}''$	$\frac{5}{16}''$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{7}{8}''$
Equal Legs.													
6 x6	...	...	...	...	...	6.037	6.880	7.687	8.494	9.302	10.07	10.85	11.62
4 x4	...	...	...	2.878	3.440	3.966	4.493	5.019	5.511	6.002	6.494	6.985	...
3½x3½	...	...	...	...	2.984	3.440	3.896	4.317	4.774	5.195	5.616	6.002	...
3 x3	...	...	1.720	2.141	2.527	2.913	3.300	3.651	4.002	...	...	...	...
2¾x2¾	...	...	1.580	1.930	2.317	2.667	2.984	...	...	...	...	...	...
2½x2½	...	...	1.439	1.755	2.071	2.387	2.703	...	...	...	...	...	...
2¼x2¼	...	...	1.299	1.580	1.860	2.141	2.387	...	...	...	...	...	...
2 x2	...	.8775	1.123	1.404	1.650	1.860	...	...	...	...	...	...	...
1¾x1¾	...	.7372	.9828	1.194	1.404	1.615	...	...	...	...	...	...	...
1½x1½	...	.6318	.8424	1.018	1.194	...	...	...	...	...	...	...	...
1¼x1¼	.3510	.5265	.6669	.8424	...	...	...	...	...	...	...	...	...
1⅛x1⅛	.3159	.4563	.5967	.7371	...	...	...	...	...	...	...	...	...
1 x1	.2808	.4212	.5265	...	...	...	...	...	...	...	...	...	...
¾x ¾	.2106	.2808	...	...	...	...	...	...	...	...	...	...	...
⅝x ⅝	.1755	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Size Inches.	$\frac{1}{8}''$	$\frac{3}{16}''$	$\frac{1}{4}''$	$\frac{5}{16}''$	$\frac{3}{8}''$	$\frac{7}{16}''$	$\frac{1}{2}''$	$\frac{9}{16}''$	$\frac{5}{8}''$	$\frac{11}{16}''$	$\frac{3}{4}''$	$\frac{13}{16}''$	$\frac{7}{8}''$
Unequal Legs													
6 x4	...	...	...	...	4.317	5.019	5.686	6.353	7.020	7.652	8.284	8.915	9.547
5 x4	...	...	...	...	3.861	4.493	5.090	5.686	6.248	6.845	7.406	7.933	8.495
5 x3½	...	...	...	...	3.651	4.212	4.774	5.335	5.897	6.423	6.950	7.476	7.968
5 x3	...	...	...	2.878	3.440	3.967	4.493	4.984	5.511	6.002	6.494	6.985	...
4 x3½	...	...	...	...	3.194	3.686	4.177	4.669	5.125	5.581	6.037	6.494	...
4 x3	...	...	...	2.492	2.984	3.440	3.896	4.317	4.774	5.195	5.616	6.002	...
3½x3	...	...	...	2.317	2.738	3.194	3.580	4.002	4.388	4.774	5.160	5.511	...
3¼x2	...	...	1.509	1.866	2.176	2.527	2.843	3.159	...	...	...	...	...
3 x2½	...	...	1.579	1.931	2.317	2.668	2.984	3.335	...	...	...	...	...
3 x2	...	...	1.439	1.755	2.071	2.387	2.703	...	...	...	...	...	...
2½x2	...	.9828	1.299	1.579	1.860	2.141	2.387	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Digitized by Google

DECIMAL PARTS OF A FOOT IN SQUARE INCHES.

Hundredths of a sq. foot.	Square Inches.	Hundredths of a sq. foot.	Square Inches.	Hundredths of a sq. foot.	Square Inches.
1	1.44	34	49.0	67	96.5
2	2.88	35	50.4	68	97.9
3	4.32	36	51.8	69	99.4
4	5.76	37	53.3	70	100.8
5	7.20	38	54.7	71	102.2
6	8.64	39	56.2	72	103.7
7	10.1	40	57.6	73	105.1
8	11.5	41	58.0	74	106.6
9	13.0	42	60.5	75	108.0
10	14.4	43	61.9	76	109.4
11	15.8	44	63.4	77	110.9
12	17.3	45	64.8	78	112.3
13	18.7	46	66.2	79	113.8
14	20.2	47	67.7	80	115.2
15	21.6	48	69.1	81	116.6
16	23.0	49	70.6	82	118.1
17	24.5	50	72.0	83	119.5
18	25.9	51	73.4	84	121.0
19	27.4	52	74.9	85	122.4
20	28.8	53	76.3	86	123.8
21	30.2	54	77.8	87	125.3
22	31.7	55	79.2	88	126.7
23	33.1	56	80.6	89	128.2
24	34.6	57	82.1	90	129.6
25	36.0	58	83.5	91	131.0
26	37.4	59	85.0	92	132.5
27	38.9	60	86.4	93	133.9
28	40.3	61	87.8	94	135.4
29	41.8	62	89.3	95	136.8
30	43.2	63	90.7	96	138.2
31	44.6	64	92.2	97	139.7
32	46.1	65	93.6	98	141.1
33	47.5	66	95.0	99	142.6
				100	144.0

Digitized by Google

TABLE OF DECIMAL EQUIVALENTS,

IN FEET AND INCHES,

of 8ths, 16ths, 32nds and 64ths of an Inch.

Fract'n of an Inch.	Decimal of an Inch.	Decimal of a Foot.
8ths.	**8ths.**	**8ths.**
1/8 —	.125	.01041
1/4 —	.250	.02083
3/8 —	.375	.03125
1/2 —	.500	.04166
5/8 —	.625	.05208
3/4 —	.750	.06250
7/8 —	.875	.07291
16ths.	**16ths.**	**16ths.**
1/16 —	.0625	.00521
3/16 —	.1875	.01562
5/16 —	.3125	.02604
7/16 —	.4375	.03645
9/16 —	.5625	.04688
11/16 —	.6875	.05729
13/16 —	.8125	.06771
15/16 —	.9375	.07812
32nds.	**32nds.**	**32nds.**
1/32 —	.03125	.002604
3/32 —	.09375	.007812
5/32 —	.15625	.013020
7/32 —	.21875	.018228
9/32 —	.28125	.023436
11/32 —	.34375	.028644
13/32 —	.40625	.033852
15/32 —	.46875	.039060
17/32 —	.53125	.044268
19/32 —	.59375	.049476
21/32 —	.65625	.054684
23/32 —	.71875	.059892
25/32 —	.78125	.065100
27/32 —	.84375	.070308
29/32 —	.90625	.075516
31/32 —	.96875	.080724

Fract'n of an Inch.	Decimal of an Inch.	Decimal of a Foot.
64ths.	**64ths.**	**64ths.**
1/64 —	.015625	.001302
3/64 —	.046875	.003906
5/64 —	.078125	.006510
7/64 —	.109375	.009114
9/64 —	.140625	.011718
11/64 —	.171875	.014322
13/64 —	.203125	.016926
15/64 —	.234375	.019530
17/64 —	.265625	.022134
19/64 —	.296875	.024738
21/64 —	.328125	.027342
23/64 —	.359375	.029946
25/64 —	.390625	.032550
27/64 —	.421875	.035154
29/64 —	.453125	.037758
31/64 —	.484375	.040362
33/64 —	.515625	.042966
35/64 —	.546875	.045570
37/64 —	.578125	.048174
39/64 —	.609375	.050778
41/64 —	.640625	.053382
43/64 —	.671875	.055986
45/64 —	.703125	.058590
47/64 —	.734375	.061194
49/64 —	.765625	.063798
51/64 —	.796875	.066402
53/64 —	.828125	.069006
55/64 —	.859375	.071610
57/64 —	.890625	.074214
59/64 —	.921875	.076818
61/64 —	.953125	.079422
63/64 —	.984375	.082026
1 —	1.00000	.085000

Digitized by Google

DECIMALS OF AN INCH FOR EACH 1/64th.

1/32ds.	1/64ths.	Decimal.	Fraction.	1/32ds.	1/64ths.	Decimal.	Fraction.
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	1–16	18	36	.5625	9–16
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	1–8	20	40	.625	5–8
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	3–16	22	44	.6875	11–16
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	1–4	24	48	.75	3–4
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	5–16	26	52	.8125	13–16
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	3–8	28	56	.875	7–8
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	7–16	30	60	.9375	15–16
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	1–2	32	64.	1.	1

Digitized by Google

DECIMAL PARTS OF A FOOT FOR EACH $\frac{1}{64}$th OF AN INCH.

INCH.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
0	0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
$\frac{1}{64}$	.0013	.0846	.1680	.2513	.3346	.4180	.5013	.5846	.6680	.7513	.8346	.9180
$\frac{1}{32}$	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
$\frac{3}{64}$	.0039	.0872	.1706	.2539	.3372	.4206	.5039	.5872	.6706	.7539	.8372	.9206
$\frac{1}{16}$	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
$\frac{5}{64}$	.0065	.0898	.1732	.2565	.3398	.4232	.5065	.5898	.6732	.7565	.8398	.9232
$\frac{3}{32}$	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
$\frac{7}{64}$	.0091	.0924	.1758	.2591	.3424	.4258	.5091	.5924	.6758	.7591	.8424	.9258
$\frac{1}{8}$	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
$\frac{9}{64}$	.0117	.0951	.1784	.2617	.3451	.4284	.5117	.5951	.6784	.7617	.8451	.9284
$\frac{5}{32}$	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
$\frac{11}{64}$	.0143	.0977	.1810	.2643	.3477	.4310	.5143	.5977	.6810	.7643	.8477	.9310
$\frac{3}{16}$	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
$\frac{13}{64}$	.0169	.1003	.1836	.2669	.3503	.4336	.5169	.6003	.6836	.7669	.8503	.9336
$\frac{7}{32}$	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
$\frac{15}{64}$	.0195	.1029	.1862	.2695	.3529	.4362	.5195	.6029	.6862	.7695	.8529	.9362
$\frac{1}{4}$	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375

Digitized by Google

DECIMAL PARTS OF A FOOT FOR EACH $\frac{1}{64}$th OF AN INCH.—Continued.

Inch.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
$\frac{17}{64}$	.0221	.1055	.1888	.2721	.3555	.4388	.5221	.6055	.6888	.7721	.8555	.9388
$\frac{9}{32}$	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401
$\frac{19}{64}$	.0247	.1081	.1914	.2747	.3581	.4414	.5247	.6081	.6914	.7747	.8581	.9414
$\frac{5}{16}$	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
$\frac{21}{64}$	.0273	.1107	.1940	.2773	.3607	.4440	.5273	.6107	.6940	.7773	.8607	.9440
$\frac{11}{32}$	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
$\frac{23}{64}$	.0299	.1133	.1966	.2799	.3633	.4466	.5299	.6133	.6966	.7799	.8633	.9466
$\frac{3}{8}$	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
$\frac{25}{64}$	.0326	.1159	.1992	.2826	.3659	.4492	.5326	.6159	.6992	.7826	.8659	.9492
$\frac{13}{32}$	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7005	.7839	.8672	.9505
$\frac{27}{64}$	.0352	.1185	.2018	.2852	.3685	.4518	.5352	.6185	.7018	.7852	.8685	.9518
$\frac{7}{16}$	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
$\frac{29}{64}$	.0378	.1211	.2044	.2878	.3711	.4544	.5378	.6211	.7044	.7878	.8711	.9544
$\frac{15}{32}$	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
$\frac{31}{64}$	.0404	.1237	.2070	.2904	.3737	.4570	.5404	.6237	.7070	.7904	.8737	.9570
$\frac{1}{2}$	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583

Digitized by Google

DECIMAL PARTS OF A FOOT FOR EACH $\frac{1}{64}$th OF AN INCH.—Continued.

INCH.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
$\frac{33}{64}$	.0430	.1263	.2096	.2930	.3763	.4596	.5430	.6263	.7096	.7930	.8763	.9596
$\frac{17}{32}$	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
$\frac{35}{64}$	.0456	.1289	.2122	.2956	.3789	.4622	.5456	.6289	.7122	.7956	.8789	.9622
$\frac{9}{16}$	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
$\frac{37}{64}$	.0482	.1315	.2148	.2982	.3815	.4648	.5482	.6315	.7148	.7982	.8815	.9648
$\frac{19}{32}$	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
$\frac{39}{64}$	.0508	.1341	.2174	.3008	.3841	.4674	.5508	.6341	.7174	.8008	.8841	.9674
$\frac{5}{8}$	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
$\frac{41}{64}$	.0534	.1367	.2201	.3034	.3867	.4701	.5534	.6367	.7201	.8034	.8867	.9701
$\frac{21}{32}$	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
$\frac{43}{64}$	.0560	.1393	.2227	.3060	.2893	.4727	.5560	.6393	.7227	.8060	.8893	.9727
$\frac{11}{16}$	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
$\frac{45}{64}$	.0586	.1419	.2253	.3086	.3919	.4753	.5586	.6419	.7253	.8086	.8919	.9753
$\frac{23}{32}$	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
$\frac{47}{64}$	.0612	.1445	.2279	.3112	.3945	.4779	.5612	.6445	.7279	.8112	.8945	.9779
$\frac{3}{4}$	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792

Digitized by Google

DECIMAL PARTS OF A FOOT FOR EACH $\frac{1}{64}$th OF AN INCH.—Continued.

INCH.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
$\frac{49}{64}$	.0638	.1471	.2305	.3138	.3971	.4805	.5638	.6471	.7305	.8138	.8971	.9805
$\frac{25}{32}$	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818
$\frac{51}{64}$	.0664	.1497	.2331	.3164	.3997	.4831	.5664	.6497	.7331	.8164	.8997	.9831
$\frac{13}{16}$	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
$\frac{53}{64}$	.0690	.1523	.2357	.3190	.4023	.4857	.5690	.6523	.7357	.8190	.9023	.9857
$\frac{27}{32}$	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
$\frac{55}{64}$	.0716	.1549	.2383	.3216	.4049	.4883	.5716	.6549	.7383	.8216	.9049	.9883
$\frac{7}{8}$	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
$\frac{57}{64}$	.0742	.1576	.2409	.3242	.4076	.4909	.5742	.6576	.7409	.8242	.9076	.9909
$\frac{29}{32}$	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
$\frac{59}{64}$	.0768	.1602	.2435	.3268	.4102	.4935	.5768	.6602	.7435	.8268	.9102	.9935
$\frac{15}{16}$	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
$\frac{61}{64}$	.0794	.1628	.2461	.3294	.4128	.4961	.5794	.6628	.7461	.8294	.9128	.9961
$\frac{31}{32}$	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
$\frac{63}{64}$	.0820	.1654	.2487	.3320	.4154	.4987	.5820	.6654	.7487	.8320	.9154	.9987
1												1.0000

Digitized by Google

MENSURATION

LENGTH.

Circumference of circle = diameter $\times$ 3.1416.
Diameter of circle = circumference $\times$ 0.3183.
Side of square of equal periphery as circle = diameter $\times$ 0.7854.
Diameter of circle of equal periphery as square = side $\times$ 1.2732.
Side of an inscribed square = diameter of circle $\times$ 0.7071.
Length of an arc = No. of degrees $\times$ diameter $\times$ 0.008727.

$$\pi = 3.14159265.$$

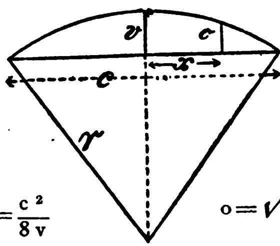
$\log.\pi = 0.4971499$

$\sqrt{\pi} = 1.772454.$

$\pi^2 = 9.869604.$

$$r = \frac{v^2 + \frac{c^2}{4}}{2v}$$

or, very nearly, $= \dfrac{c^2}{8v}$



$\dfrac{1}{\pi} = 0.318310.$

$\dfrac{1}{\pi^2} = 0.101321.$

$\sqrt{\dfrac{1}{\pi}} = 0.564190.$

$$o = \sqrt{r^2 - x^2} - (r - v)$$

$$v = r - \sqrt{r^2 - \frac{c^2}{4}} \text{ or, very nearly,} = \frac{c^2}{8r}$$

AREA.

Triangle = base $\times$ half perpendicular height.
Parallelogram = base $\times$ perpendicular height.
Trapezoid = half the sum of the parallel sides $\times$ perpendicular height.
Trapezium, found by dividing in two triangles.
Circle = diameter squared $\times$ 0.7854; or,
= circumference squared $\times$ 0.07958.
Sector of circle = length of arc $\times$ half radius.

Digitized by Google

MENSURATION.—Continued.

Segment of circle = area of sector less triangle; also, for flat segments very nearly $= \frac{4\,v}{3}\sqrt{0.388\,v^2 + \frac{c^2}{4}}$

Side of square of equal area as circle = diameter × 0.8862; also = circumference × 0.2821.

Diameter of circle of equal area as square = side × 1.1284.

Parabola = base × ⅔ height.

Ellipse = long diameter × short diameter × 0.7854.

Regular polygon = sum of sides × half perpendicular distance from center to sides.

Surface of cylinder = circumference × height + area of both ends.

Surface of sphere = diameter squared × 3.1416.
also = circumference × diameter.

Surface of a right pyramid or cone = periphery or circumference of base × half slant height.

Surface of a frustrum of a regular right pyramid or cone = sum of peripheries or circumferences of the two ends × half slant height + area of both ends.

SOLID CONTENTS.

Prism, right or oblique = area of base × perpendicular height.

Cylinder, right or oblique = area of section at right angles to sides × length of side.

Sphere = diameter cubed × 0.5236.
also = surface × ⅙ diameter.

Pyramid or cone, right or oblique, regular or irregular = area of base × ⅓ perpendicular height.

PRISMOIDAL FORMULA.

A prismoid is a solid bounded by six plane surfaces, only two of which are parallel.

To find the contents of a prismoid, add together the areas of the two parallel surfaces, and four times the area of a section taken midway between and parallel to them, and multiply the sum by ⅙th of the perpendicular distance between the parallel surfaces.

Digitized by Google

AREAS OF FLAT ROLLED BARS.

For Thicknesses from $\frac{1}{16}$ in. to 2 in. and Widths from 1 in. to 12¾ in.

Thickness in Inches.	1″	1¼″	1½″	1¾″	2″	2¼″	2½″	2¾″	12″
$\frac{1}{16}$	.063	.078	.094	.109	.125	.141	.156	.172	.750
$\frac{1}{8}$	.125	.156	.188	.219	.250	.281	.313	.344	1.50
$\frac{3}{16}$	.188	.234	.281	.328	.375	.422	.469	.516	2.25
$\frac{1}{4}$	.250	.313	.375	.438	.500	.563	.625	.688	3.00
$\frac{5}{16}$	.313	.391	.469	.547	.625	.703	.781	.859	3.75
$\frac{3}{8}$	.375	.469	.563	.656	.750	.844	.938	1.03	4.50
$\frac{7}{16}$	.438	.547	.656	.766	.875	.984	1.09	1.20	5.25
$\frac{1}{2}$	.500	.625	.750	.875	1.00	1.13	1.25	1.38	6.00
$\frac{9}{16}$	.563	.703	.844	.984	1.13	1.27	1.41	1.55	6.75
$\frac{5}{8}$	.625	.781	.938	1.09	1.25	1.41	1.56	1.72	7.50
$\frac{11}{16}$	.688	.859	1.03	1.20	1.38	1.55	1.72	1.89	8.25
$\frac{3}{4}$	.750	.938	1.13	1.31	1.50	1.69	1.88	2.06	9.00
$\frac{13}{16}$	.813	1.02	1.22	1.42	1.63	1.83	2.03	2.23	9.75
$\frac{7}{8}$	.875	1.09	1.31	1.53	1.75	1.97	2.19	2.41	10.50
$\frac{15}{16}$	.938	1.17	1.41	1.64	1.88	2.11	2.34	2.58	11.25
1	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	12.00
$1\frac{1}{16}$	1.06	1.33	1.59	1.86	2.13	2.39	2.66	2.92	12.75
$1\frac{1}{8}$	1.13	1.41	1.69	1.97	2.25	2.53	2.81	3.09	13.50
$1\frac{3}{16}$	1.19	1.48	1.78	2.08	2.38	2.67	2.97	3.27	14.25
$1\frac{1}{4}$	1.25	1.56	1.88	2.19	2.50	2.81	3.13	3.44	15.00
$1\frac{5}{16}$	1.31	1.64	1.97	2.30	2.63	2.95	3.28	3.61	15.75
$1\frac{3}{8}$	1.38	1.72	2.06	2.41	2.75	3.09	3.44	3.78	16.50
$1\frac{7}{16}$	1.44	1.80	2.16	2.52	2.88	3.23	3.59	3.95	17.25
$1\frac{1}{2}$	1.50	1.88	2.25	2.63	3.00	3.38	3.75	4.13	18.00
$1\frac{9}{16}$	1.56	1.95	2.34	2.73	3.13	3.52	3.91	4.30	18.75
$1\frac{5}{8}$	1.63	2.03	2.44	2.84	3.25	3.66	4.06	4.47	19.50
$1\frac{11}{16}$	1.69	2.11	2.53	2.95	3.38	3.80	4.22	4.64	20.25
$1\frac{3}{4}$	1.75	2.19	2.63	3.06	3.50	3.94	4.38	4.81	21.00
$1\frac{13}{16}$	1.81	2.27	2.72	3.17	3.63	4.08	4.53	4.98	21.75
$1\frac{7}{8}$	1.88	2.34	2.81	3.28	3.75	4.22	4.69	5.16	22.50
$1\frac{15}{16}$	1.94	2.42	2.91	3.39	3.88	4.36	4.84	5.33	23.25
2	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	24.00

Digitized by Google

AREAS OF FLAT ROLLED BARS.

(CONTINUED.)

Thickness in Inches.	3″	3¼″	3½″	3¾″	4″	4¼″	4½″	4¾″	12″
1/16	.188	.203	.219	.234	.250	.266	.281	.297	.750
1/8	.375	.406	.438	.469	.500	.531	.563	.594	1.50
3/16	.563	.609	.656	.703	.750	.797	.844	.891	2.25
1/4	.750	.813	.875	.938	1.00	1.06	1.13	1.19	3.00
5/16	.938	1.02	1.09	1.17	1.25	1.33	1.41	1.48	3.75
3/8	1.13	1.22	1.31	1.41	1.50	1.59	1.69	1.78	4.50
7/16	1.31	1.42	1.53	1.64	1.75	1.86	1.97	2.08	5.25
1/2	1.50	1.63	1.75	1.88	2.00	2.13	2.25	2.38	6.00
9/16	1.69	1.83	1.97	2.11	2.25	2.39	2.53	2.67	6.75
5/8	1.88	2.03	2.19	2.34	2.50	2.66	2.81	2.97	7.50
11/16	2.06	2.23	2.41	2.58	2.75	2.92	3.09	3.27	8.25
3/4	2.25	2.44	2.63	2.81	3.00	3.19	3.38	3.56	9.00
13/16	2.44	2.64	2.84	3.05	3.25	3.45	3.66	3.86	9.75
7/8	2.63	2.84	3.06	3.28	3.50	3.72	3.94	4.16	10.50
15/16	2.81	3.05	3.28	3.52	3.75	3.98	4.22	4.45	11.25
1	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	12.00
1 1/16	3.19	3.45	3.72	3.98	4.25	4.52	4.78	5.05	12.75
1 1/8	3.38	3.66	3.94	4.22	4.50	4.78	5.06	5.34	13.50
1 3/16	3.56	3.86	4.16	4.45	4.75	5.05	5.34	5.64	14.25
1 1/4	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	15.00
1 5/16	3.94	4.27	4.59	4.92	5.25	5.58	5.91	6.23	15.75
1 3/8	4.13	4.47	4.81	5.16	5.50	5.84	6.19	6.53	16.50
1 7/16	4.31	4.67	5.03	5.39	5.75	6.11	6.47	6.83	17.25
1 1/2	4.50	4.88	5.25	5.63	6.00	6.38	6.75	7.13	18.00
1 9/16	4.69	5.08	5.47	5.86	6.25	6.64	7.03	7.42	18.75
1 5/8	4.88	5.28	5.69	6.09	6.50	6.91	7.31	7.72	19.50
1 11/16	5.06	5.48	5.91	6.33	6.75	7.17	7.59	8.02	20.25
1 3/4	5.25	5.69	6.13	6.56	7.00	7.44	7.88	8.31	21.00
1 13/16	5.44	5.89	6.34	6.80	7.25	7.70	8.16	8.61	21.75
1 7/8	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.91	22.50
1 15/16	5.81	6.30	6.78	7.27	7.75	8.23	8.72	9.20	23.25
2	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	24.00

Digitized by Google

AREAS OF FLAT ROLLED BARS.

(CONTINUED.)

Thickness in Inches.	5″	5¼″	5½″	5¾″	6″	6¼″	6½″	6¾″	12″
$\frac{1}{16}$	.313	.328	.344	.359	.375	.391	.406	.422	.750
$\frac{1}{8}$	.625	.656	.688	.719	.750	.781	.813	.844	1.50
$\frac{3}{16}$	.938	.984	1.03	1.08	1.13	1.17	1.22	1.27	2.25
$\frac{1}{4}$	1.25	1.31	1.38	1.44	1.50	1.56	1.63	1.69	3.00
$\frac{5}{16}$	1.56	1.64	1.72	1.80	1.88	1.95	2.03	2.11	3.75
$\frac{3}{8}$	1.88	1.97	2.06	2.16	2.25	2.34	2.44	2.53	4.50
$\frac{7}{16}$	2.19	2.30	2.41	2.52	2.63	2.73	2.84	2.95	5.25
$\frac{1}{2}$	2.50	2.63	2.75	2.88	3.00	3.13	3.25	3.38	6.00
$\frac{9}{16}$	2.81	2.95	3.09	3.23	3.38	3.52	3.66	3.80	6.75
$\frac{5}{8}$	3.13	3.28	3.44	3.59	3.75	3.91	4.06	4.22	7.50
$\frac{11}{16}$	3.44	3.61	3.78	3.95	4.13	4.30	4.47	4.64	8.25
$\frac{3}{4}$	3.75	3.94	4.13	4.31	4.50	4.69	4.88	5.06	9.75
$\frac{13}{16}$	4.06	4.27	4.47	4.67	4.88	5.08	5.28	5.48	9.75
$\frac{7}{8}$	4.38	4.59	4.81	5.03	5.25	5.47	5.69	5.91	10.50
$\frac{15}{16}$	4.69	4.92	5.16	5.39	5.63	5.86	6.09	6.33	11.25
1	5.00	5.25	5.50	5.75	6.00	6.25	6.50	6.75	12.00
$1\frac{1}{16}$	5.31	5.58	5.84	6.11	6.38	6.64	6.91	7.17	12.75
$1\frac{1}{8}$	5.63	5.91	6.19	6.47	6.75	7.03	7.31	7.59	13.50
$1\frac{3}{16}$	5.94	6.23	6.53	6.83	7.13	7.42	7.72	8.02	14.25
$1\frac{1}{4}$	6.25	6.56	6.88	7.19	7.50	7.81	8.13	8.44	15.00
$1\frac{5}{16}$	6.56	6.89	7.22	7.55	7.88	8.20	8.53	8.86	15.75
$1\frac{3}{8}$	6.88	7.22	7.56	7.91	8.25	8.59	8.94	9.28	16.50
$1\frac{7}{16}$	7.19	7.55	7.91	8.27	8.63	8.98	9.34	9.70	17.25
$1\frac{1}{2}$	7.50	7.88	8.25	8.63	9.00	9.38	9.75	10.13	18.00
$1\frac{9}{16}$	7.81	8.20	8.59	8.98	9.38	9.77	10.16	10.55	18.75
$1\frac{5}{8}$	8.13	8.53	8.94	9.34	9.75	10.16	10.56	10.97	19.50
$1\frac{11}{16}$	8.44	8.86	9.28	9.70	10.13	10.55	10.97	11.39	20.25
$1\frac{3}{4}$	8.75	9.19	9.63	10.06	10.50	10.94	11.38	11.81	21.00
$1\frac{13}{16}$	9.06	9.52	9.97	10.42	10.88	11.33	11.78	12.23	21.75
$1\frac{7}{8}$	9.38	9.84	10.31	10.78	11.25	11.72	12.19	12.66	22.50
$1\frac{15}{16}$	9.69	10.17	10.66	11.14	11.63	12.11	12.59	13.08	23.25
2	10.00	10.50	11.00	11.50	12.00	12.50	13.00	13.50	24.00

Digitized by Google

AREAS OF FLAT ROLLED BARS

(CONTINUED.)

Thickness in Inches.	7″	7¼″	7½″	7¾″	8″	8¼″	8½″	8¾″	12″
1/16	.438	.453	.469	.484	.500	.516	.531	.547	.750
1/8	.875	.906	9.38	.969	1.00	1.03	1.06	1.09	1.50
3/16	1.31	1.36	1.41	1.45	1.50	1.55	1.59	1.64	2.25
1/4	1.75	1.81	1.88	1.94	2.00	2.06	2.13	2.19	3.00
5/16	2.19	2.27	2.34	2.42	2.50	2.58	2.66	2.73	3.75
3/8	2.63	2.72	2.81	2.91	3.00	3.09	3.19	3.28	4.50
7/16	3.06	3.17	3.28	3.39	3.50	3.61	3.72	3.83	5.25
1/2	3.50	3.63	3.75	3.88	4.00	4.13	4.25	4.38	6.00
9/16	3.94	4.08	4.22	4.36	4.50	4.64	4.78	4.92	6.75
5/8	4.38	4.53	4.69	4.84	5.00	5.16	5.31	5.47	7.50
11/16	4.81	4.98	5.16	5.33	5.50	5.67	5.84	6.02	8.25
3/4	5.25	5.44	5.63	5.81	6.00	6.19	6.38	6.56	9.00
13/16	5.69	5.89	6.09	6.30	6.50	6.70	6.91	7.11	9.75
7/8	6.13	6.34	6.56	6.78	7.00	7.22	7.44	7.66	10.50
15/16	6.56	6.80	7.03	7.27	7.50	7.73	7.97	8.20	11.25
1	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	12.00
1 1/16	7.44	7.70	7.97	8.23	8.50	8.77	9.03	9.30	12.75
1 1/8	7.88	8.16	8.44	8.72	9.00	9.28	9.56	9.84	13.50
1 3/16	8.31	8.61	8.91	9.20	9.50	9.80	10.09	10.39	14.25
1 1/4	8.75	9.06	9.38	9.69	10.00	10.31	10.63	10.94	15.00
1 5/16	9.19	9.52	9.84	10.17	10.50	10.83	11.16	11.48	15.75
1 3/8	9.63	9.97	10.31	10.66	11.00	11.34	11.69	12.03	16.50
1 7/16	10.06	10.42	10.78	11.14	11.50	11.86	12.22	12.58	17.25
1 1/2	10.50	10.88	11.25	11.63	12.00	12.38	12.75	13.13	18.00
1 9/16	10.94	11.33	11.72	12.11	12.50	12.89	13.28	13.67	18.75
1 5/8	11.38	11.78	12.19	12.59	13.00	13.41	13.81	14.22	19.50
1 11/16	11.81	12.23	12.66	13.08	13.50	13.92	14.34	14.77	20.25
1 3/4	12.25	12.69	13.13	13.56	14.00	14.44	14.88	15.31	21.00
1 13/16	12.69	13.14	13.59	14.05	14.50	14.95	15.41	15.86	21.75
1 7/8	13.13	13.59	14.06	14.53	15.00	15.47	15.94	16.41	22.50
1 15/16	13.56	14.05	14.53	15.02	15.50	15.98	16.47	16.95	23.25
2	14.00	14.50	15.00	15.50	16.00	16.50	17.00	17.50	24.00

Digitized by Google

AREAS OF FLAT ROLLED BARS.

(CONTINUED.)

Thickness in Inches.	9″	9¼″	9½″	9¾″	10″	10¼″	10½″	10¾″	12″
$\frac{1}{16}$	.563	.578	.594	.609	.625	.641	.656	.672	.750
$\frac{1}{8}$	1.13	1.16	1.19	1.22	1.25	1.28	1.31	1.34	1.50
$\frac{3}{16}$	1.69	1.73	1.78	1.83	1.88	1.92	1.97	2.02	2.25
$\frac{1}{4}$	2.25	2.31	2.38	2.44	2.50	2.56	2.63	2.69	3.00
$\frac{5}{16}$	2.81	2.89	2.97	3.05	3.13	3.20	3.28	3.36	3.75
$\frac{3}{8}$	3.38	3.47	3.56	3.66	3.75	3.84	3.94	4.03	4.50
$\frac{7}{16}$	3.94	4.05	4.16	4.27	4.38	4.48	4.59	4.70	5.25
$\frac{1}{2}$	4.50	4.63	4.75	4.88	5.00	5.13	5.25	5.38	6.00
$\frac{9}{16}$	5.06	5.20	5.34	5.48	5.63	5.77	5.91	6.05	6.75
$\frac{5}{8}$	5.63	5.78	5.94	6.09	6.25	6.41	6.56	6.72	7.50
$\frac{11}{16}$	6.19	6.36	6.53	6.70	6.88	7.05	7.22	7.39	8.25
$\frac{3}{4}$	6.75	6.94	7.13	7.31	7.50	7.69	7.88	8.06	9.00
$\frac{13}{16}$	7.31	7.52	7.72	7.92	8.13	8.33	8.53	8.73	9.75
$\frac{7}{8}$	7.88	8.09	8.31	8.53	8.75	8.97	9.19	9.41	10.50
$\frac{15}{16}$	8.44	8.67	8.91	9.14	9.38	9.61	9.84	10.08	11.25
1	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	12.00
$1\frac{1}{16}$	9.56	9.83	10.09	10.36	10.63	10.89	11.16	11.42	12.75
$1\frac{1}{8}$	10.13	10.41	10.69	10.97	11.25	11.53	11.81	12.09	13.50
$1\frac{3}{16}$	10.69	10.98	11.28	11.58	11.88	12.17	12.47	12.77	14.25
$1\frac{1}{4}$	11.25	11.56	11.88	12.19	12.50	12.81	13.13	13.44	15.00
$1\frac{5}{16}$	11.81	12.14	12.47	12.80	13.13	13.45	13.78	14.11	15.75
$1\frac{3}{8}$	12.38	12.72	13.06	13.41	13.75	14.09	14.44	14.78	16.50
$1\frac{7}{16}$	12.94	13.30	13.66	14.02	14.38	14.73	15.09	15.45	17.25
$1\frac{1}{2}$	13.50	13.88	14.25	14.63	15.00	15.38	15.75	16.13	18.00
$1\frac{9}{16}$	14.06	14.45	14.84	15.23	15.63	16.02	16.41	16.80	18.75
$1\frac{5}{8}$	14.63	15.03	15.44	15.84	16.25	16.66	17.06	17.47	19.50
$1\frac{11}{16}$	15.19	15.61	16.03	16.45	16.88	17.30	17.72	18.14	20.25
$1\frac{3}{4}$	15.75	16.19	16.63	17.06	17.50	17.94	18.38	18.81	21.00
$1\frac{13}{16}$	16.31	16.77	17.22	17.67	18.13	18.58	19.03	19.48	21.75
$1\frac{7}{8}$	16.88	17.34	17.81	18.28	18.75	19.22	19.69	20.16	22.50
$1\frac{15}{16}$	17.44	17.92	18.41	18.89	19.38	19.86	20.34	20.83	23.25
2	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50	24.00

Digitized by Google

AREAS OF FLAT ROLLED BARS.

(CONTINUED.)

Thickness in Inches.	11″	11¼″	11½″	11¾″	12″	12¼″	12½″	12¾″
1/16	.688	.703	.719	.734	.750	.766	.781	.797
1/8	1.38	1.41	1.44	1.47	1.50	1.53	1.56	1.59
3/16	2.06	2.11	2.16	2.20	2.25	2.30	2.34	2.39
1/4	2.75	2.81	2.88	2.94	3.00	3.06	3.13	3.19
5/16	3.44	3.52	3.59	3.67	3.75	3.83	3.91	3.98
3/8	4.13	4.22	4.31	4.41	4.50	4.59	4.69	4.78
7/16	4.81	4.92	5.03	5.14	5.25	5.36	5.47	5.58
1/2	5.50	5.63	5.75	5.88	6.00	6.13	6.25	6.38
9/16	6.19	6.33	6.47	6.61	6.75	6.89	7.03	7.17
5/8	6.88	7.03	7.19	7.34	7.50	7.66	7.81	7.97
11/16	7.56	7.73	7.91	8.08	8.25	8.42	8.59	8.77
3/4	8.25	8.44	8.63	8.81	9.00	9.19	9.38	9.56
13/16	8.94	9.14	9.34	9.55	9.75	9.95	10.16	10.36
7/8	9.63	9.84	10.06	10.28	10.50	10.72	10.94	11.16
15/16	10.31	10.55	10.78	11.02	11.25	11.48	11.72	11.95
1	11.00	11.25	11.50	11.75	12.00	12.25	12.50	12.75
1 1/16	11.69	11.95	12.22	12.48	12.75	13.02	13.28	13.55
1 1/8	12.38	12.66	12.94	13.22	13.50	13.78	14.06	14.34
1 3/16	13.06	13.36	13.66	13.95	14.25	14.55	14.84	15.14
1 1/2	13.75	14.06	14.38	14.69	15.00	15.31	15.63	15.94
1 5/16	14.44	14.77	15.09	15.42	15.75	16.08	16.41	16.73
1 3/8	15.13	15.47	15.81	16.16	16.50	16.84	17.19	17.53
1 7/16	15.81	16.17	16.53	16.89	17.25	17.61	17.97	18.33
1 1/2	16.50	16.88	17.25	17.63	18.00	18.38	18.75	19.13
1 9/16	17.19	17.58	17.97	18.36	18.75	19.14	19.53	19.92
1 5/8	17.88	18.28	18.69	19.09	19.50	19.91	20.31	20.72
1 11/16	18.56	18.98	19.41	19.83	20.25	20.67	21.09	21.52
1 3/4	19.25	19.69	20.13	20.56	21.00	21.44	21.88	22.31
1 13/16	19.94	20.39	20.84	21.30	21.75	22.20	22.66	23.11
1 7/8	20.63	21.09	21.56	22.03	22.50	22.97	23.44	23.91
1 15/16	21.31	21.80	22.28	22.77	23.25	23.73	24.22	24.70
2	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50

The areas for 12″ width are repeated on each page to facilitate making the additions necessary to obtain the areas of plates wider than 12″. Thus, to find the area of 15¼″ × 7/8″, add the areas to be found in the same line for 3¼ × 7/8 and 12″ × 7/8 = 2.84 + 10.50 = 13.34 Square Inches.

Areas and Circumferences of Circles

From 1 to 50 Feet [*advancing by an Inch*], **or from 1 to 50 Inches** [*advancing by a Twelfth*].

Dia.	Area. Feet.	Circum. Feet.
1ft.	·7854	3·1416
1	·9217	3·4034
2	1·0690	3·6652
3	1·2272	3·9270
4	1·3963	4·1888
5	1·5763	4·4506
6	1·7671	4·7124
7	1·9690	4·9742
8	2·1817	5·2360
9	2·4053	5·4978
10	2·6398	5·7596
11	2·8853	6·0214
2ft.	3·1416	6·2832
1	3·4088	6·5450
2	3·6870	6·8068
3	3·9761	7·0686
4	4·2761	7·3304
5	4·5869	7·5922
6	4·9087	7·8540
7	5·2415	8·1158
8	5·5852	8·3776
9	5·9396	8·6394
10	6·3050	8·9012
11	6·6814	9·1630
3ft.	7·0686	9·4248
1	7·4668	9·6866
2	7·8758	9·9484
3	8·2958	10·2102
4	8·7267	10·4720
5	9·1685	10·7338
6	9·6211	10·9956
7	10·0848	11·2574
8	10·5593	11·5192
9	11·0447	11·7810
10	11·5410	12·0428
11	12·0483	12·3046
4ft.	12·5664	12·5664
1	13·0955	12·8282
2	13·6354	13·0900
3	14·1863	13·3518

Dia.	Area. Feet.	Circum. Feet.
4	14·7481	13·6136
5	15·3208	13·8754
6	15·9043	14·1372
7	16·4989	14.3990
8	17·1043	14.6608
9	17·7206	14·9226
10	18·3478	15·1844
11	18·9859	15·4462
5ft.	19·6350	15·7080
1	20·2949	15·9698
2	20·9658	16·2316
3	21·6476	16·4934
4	22·3403	16·7552
5	23·0439	17·0170
6	23·7583	17·2788
7	24·4837	17·5406
8	25.2201	17·8024
9	25.9673	18·0642
10	26·7254	18·3260
11	27·4944	18·5878
6ft.	28·2744	18·8496
1	29·0653	19·1114
2	29·8670	19·3732
3	30·6797	19·6350
4	31·5033	19·8968
5	32·3378	20·1586
6	33·1831	20·4204
7	34·0394	20·6822
8	34·9067	20·9440
9	35·7848	21·2058
10	36·6738	21·4676
11	37·5738	21·7294
7ft.	38·4846	21·9912
1	39·4064	22·2530
2	40·3390	22·5148
3	41·2826	22·7766
4	42·2371	23·0384
5	43·2025	23·3002
6	44·1787	23·5620
7	45·1659	23·8238

Dia.	Area. Feet.	Circum. Feet.
8	46·1641	24·0856
9	47·1731	24·3474
10	48·1930	24·6092
11	49·2238	24·8710
8ft.	50·2656	25·1328
1	51·3183	25·3946
2	52·3818	25·6564
3	53·4563	25·9182
4	54·5417	26·1800
5	55·6380	26·4418
6	56·7451	26·7036
7	57·8632	26·9654
8	58·9923	27·2272
9	60·1322	27·4890
10	61·2830	27·7508
11	62·4448	28·0126
9ft.	63·6174	28·2744
1	64·8010	28·5362
2	65·9954	28·7980
3	67·2008	29·0598
4	68·4170	29·3216
5	69·6442	29·5834
6	70·8823	29·8452
7	72·1314	30·1070
8	73·3913	30·3688
9	74·6621	30·6306
10	75·9439	30·8924
11	77·2365	31·1542
10ft.	78·5400	31·4160
1	79·8545	31·6778
2	81·1798	31·9396
3	82·5161	32·2014
4	83·8633	32·4632
5	85·2214	32·7250
6	86·5903	32·9868
7	87·9703	33·2486
8	89·3611	33·5104
9	90·7628	33·7722
10	92·1754	34·0340
11	93·5990	34·2958

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
	Feet.	Feet.		Feet.	Feet.		Feet.	Feet.
11*ft.*	95·0334	34·5576	4	161·3561	45·0296	8	245·1321	55·5016
1	96·4787	34·8194	5	163·2378	45·2914	9	247·4501	55·7634
2	97·9350	35·0812	6	165·1303	45·5532	10	249·7790	56·0252
3	99·4022	35·3430	7	167·0338	45·8150	11	252·1188	56·2870
4	100·8803	35·6048	8	168·9483	46·0768	18*ft.*	254·4696	56·5488
5	102·3693	35·8666	9	170·8736	46·3386	1	256·8312	56·8106
6	103·8691	36·1284	10	172·8098	46·6004	2	259·2038	57·0724
7	105·3800	36·3902	11	174·7569	46·8622	3	261·5873	57·3342
8	106·9017	36·6520	15*ft.*	176·7150	47·1240	4	263·9817	57·5960
9	108·4343	36·9138	1	178·6840	47·3858	5	266·3869	57·8578
10	109·9778	37·1756	2	180·6638	47·6476	6	268·8031	58·1196
11	111·5323	37·4374	3	182·6546	47·9094	7	271·2302	58·3814
12*ft.*	113·0976	37·6992	4	184·6563	48·1712	8	273·6683	58·6432
1	114·6739	37·9610	5	186·6689	48·4330	9	276·1172	58·9050
2	116·2610	38·2228	6	188·6924	48·6948	10	278·5770	59·1668
3	117·8591	38·4846	7	190·7267	48·9566	11	281·0477	59·4286
4	119·4680	38·7464	8	192·7721	49·2184	19*ft.*	283·5294	59·6904
5	121·0880	39·0082	9	194·8283	49·4802	1	286·0219	59·9522
6	122·7187	39·2700	10	196·8954	49·7420	2	288·5255	60·2140
7	124·3605	39·5318	11	198·9734	50·0038	3	291·0398	60·4758
8	126·0131	39·7936	16*ft.*	201·0624	50·2656	4	293·5651	60·7376
9	127·6766	40·0554	1	203·1622	50·5274	5	296·1012	60·9994
10	129·3510	40·3172	2	205·2730	50·7892	6	298·6483	61·2612
11	131.0363	40·5790	3	207·3947	51·0510	7	301·2064	61·5232
13*ft.*	132·7326	40·8408	4	209·5273	51·3128	8	303·7753	61·7848
1	134·4398	41·1026	5	211·6707	51·5746	9	306·3551	62·0466
2	136·1578	41·3644	6	213·8252	51·8364	10	308·9458	62·3084
3	137·8868	41·6262	7	215·9904	52·0982	11	311·5475	62·5702
4	139·6267	41·8880	8	218·1667	52·3600	20*ft.*	314·1600	62·8320
5	141·3774	42·1498	9	220·3538	52·6218	1	316·7834	63·0938
6	143·1391	42·4116	10	222·5518	52·8836	2	319·4178	63·3556
7	144·9117	42·6734	11	224·7607	53·1454	3	322·0631	63·6174
8	146·6953	42·9352	17*ft.*	226·9806	53·4072	4	324·7193	63·8792
9	148·4897	43·1970	1	229·2113	53·6690	5	327·3864	64·1410
10	150·2950	43·4588	2	231·4530	53·9308	6	330·0643	64·4028
11	152·1113	43·7206	3	233·7056	54·1926	7	332·7532	64·6646
14*ft.*	153·9384	43·9824	4	235·9691	54·4544	8	335·4531	64·9264
1	155·7764	44·2442	5	238·2434	54·7162	9	338·1638	65·1882
2	157·6254	44·5060	6	240·5287	54·9780	10	340·8854	65·4500
8	159·4853	44·7678	7	242·8249	55·2398	11	343·6180	65·7118

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
	Feet.	Feet.		Feet.	Feet.		Feet.	Feet.
21*ft.*	346·3614	65·9736	4	465·0440	76·4456	8	601·1800	86·9176
1	349·1157	66·2354	5	468·2347	76·7074	9	604·8071	87·1794
2	351·8810	66·4972	6	471·4363	76·9692	10	608·4450	87·4412
3	354·6572	66·7590	7	474·6488	77·2310	11	612·0938	87·7030
4	357·4442	67·0208	8	477·8723	77·4928	28*ft.*	615·7536	87·9648
5	360·2422	67·2826	9	481·1066	77·7546	1	619·4242	88·2266
6	363·0511	67·5444	10	484·3518	78·0164	2	623·1058	88·4884
7	365·8709	67·8062	11	487·6076	78·2782	3	626·7983	88·7502
8	368·7017	68·0680	25*ft.*	490·8750	78·5400	4	630·5016	89·0120
9	371·5433	68·3298	1	494·1529	78·8018	5	634·2159	89·2738
10	374·3958	68·5916	2	497·4418	79·0636	6	637·9411	89·5356
11	377·2592	68·8534	3	500·7416	79·3254	7	641·6772	89·7974
22*ft.*	380·1336	69·1152	4	504·0523	79·5872	8	645·4243	90·0592
1	383·0188	69·3770	5	507·3738	79·8490	9	649·1822	90·3210
2	385·9150	69·6388	6	510·7063	80·1108	10	652·9510	90·5828
3	388·8221	69·9006	7	514· 492	80·3726	11	656·7307	90·8446
4	391·7400	70·1624	8	517·4040	80·6344	29*ft.*	660·5214	91·1064
5	394·6689	70·4242	9	520·7603	80·8962	1	664·3229	91·3682
6	397·6087	70·6860	10	524·1454	81·1580	2	668·1354	91·6300
7	400·5594	70·9478	11	527·5324	81·4198	3	671·9588	91·8918
8	403·5211	71·2096	26*ft.*	530·9304	81·6816	4	675·7931	92·1536
9	406·4936	71·4714	1	534·3392	81·9434	5	679·6382	92·4154
10	409·4770	71·7332	2	537·7590	82·2052	6	683·4943	92·6772
11	412·4713	71·9950	3	541·1897	82·4670	7	687·3613	92·9390
23*ft.*	415·4766	72·2568	4	544·6313	82·7288	8	691·2393	93·2008
1	418·4927	72·5186	5	548·0837	82·9906	9	695·1281	93·4626
2	421·5198	72·7804	6	551·5471	83·2524	10	699·0278	93·7244
3	424·5578	73·0422	7	555·0214	83·5142	11	702·9384	93·9862
4	427·6067	73·3040	8	558·5066	83·7760	30*ft.*	706·8600	94·2480
5	430·6664	73·5658	9	562·0028	84·0378	1	710·7924	94·5098
6	433·7371	73·8276	10	565·5098	84·2996	2	714·7358	94·7716
7	436·8187	74·0894	11	569·0277	84·5614	3	718·6901	95·0334
8	439.9111	74·3512	27*ft.*	572·5566	84·8232	4	722·6553	95·2952
9	443.0147	74·6130	1	576·0963	85·0850	5	726·6313	95·5570
10	446·1290	74·8748	2	579·6467	85·3468	6	730·6183	95·8188
11	449·2542	75·1366	3	583·2086	85·6086	7	734·6162	96·0806
24*ft.*	452·3904	75·3984	4	586·7810	85·8704	8	738·6251	96·3424
1	455·5374	75·6602	5	590·3644	86·1322	9	742·6448	96·6042
2	458·6954	75·9220	6	593·9587	86·3940	10	746·6754	96·8660
3	461·8643	76·1838	7	597·5639	86·6558	11	750·7164	97·1278

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area. Feet.	Circum. Feet.
31*ft.*	754·7694	97·3896
1	758·8327	97·6514
2	762·9070	97·9132
3	766·9922	98·1750
4	771·0883	98·4368
5	775·1952	98·6986
6	779·3131	98·9604
7	783·4419	99·2222
8	787·5817	99·4840
9	791·7323	99·7458
10	795·8938	100·0076
11	800·0662	100·2694
32*ft.*	804·2496	100·5312
1	808·4439	100·7930
2	812·6490	101·0548
3	816·8651	101·3166
4	821·0920	101·5784
5	825·3299	101·8402
6	829·5787	102·1020
7	833·8384	102·3638
8	838·1091	102·6256
9	842·3906	102·8874
10	846·6830	103·1492
11	850·9863	103·4110
33*ft.*	855·3006	103·6728
1	859·6257	103·9346
2	863·9618	104·1964
3	868·3088	104·4582
4	872·6667	104·7200
5	877·0354	104·9818
6	881·4151	105·2436
7	885·8057	105·5054
8	890·2073	105·7672
9	894·6197	106·0290
10	899·0430	106·2908
11	903·4772	106·5526
34*ft.*	907·9224	106·8144
1	912·3784	107·0762
2	916·8454	107·3380
3	921·3233	107·5998

Dia.	Area. Feet.	Circum. Feet.
4	925·8120	107·8616
5	930·3117	108·1234
6	934·8223	108·3852
7	939·3439	108·6470
8	943·8763	108·9088
9	948·4196	109·1706
10	952·9738	109·4324
11	957·5392	109·6942
35*ft.*	962·1150	109·9560
1	966·7019	110·2178
2	971·2998	110·4796
3	975·9086	110·7414
4	980·5287	111·0032
5	985·1588	111·2650
6	989·8005	111·5268
7	994·4527	111·7886
8	999·1160	112·0504
9	1003·7903	112·3122
10	1008·4754	112·5740
11	1013·1714	112·8358
36*ft.*	1017·8784	113·0976
1	1022·5962	113·3594
2	1027·3250	113·6212
3	1032·0647	113·8830
4	1036·8153	114·1448
5	1041·5767	114·4066
6	1046·3491	114·6684
7	1051·1324	114·9302
8	1055·9266	115·1920
9	1060·7318	115·4538
10	1065·5478	115·7156
11	1070·3747	115·9774
37*ft.*	1075·2126	116·2392
1	1080·0613	116·5010
2	1084·9210	116·7628
3	1089·7916	117·0246
4	1094·6731	117·2864
5	1099·5654	117·5482
6	1104·4687	117·8100
7	1109·3839	118·0718

Dia.	Area. Feet.	Circum. Feet.
8	1114·3080	118·3336
9	1119·2441	118·5954
10	1124·1910	118·8572
11	1129·1489	119·1190
38*ft.*	1134·1176	119·3808
1	1139·0972	119·6426
2	1144·0878	119·9044
3	1149·0893	120·1662
4	1154·1017	120·4280
5	1159·1249	120·6898
6	1164·1591	120·9516
7	1169·2042	121·2134
8	1174·2603	121·4758
9	1179·3272	121·7370
10	1184·4050	121·9988
11	1189·4937	122·2606
39*ft.*	1194·5934	122·5224
1	1199·7039	122·7848
2	1204·8254	123·0460
3	1209·9578	123·3078
4	1215·1010	123·5696
5	1220·2552	123·8314
6	1225·4203	124·0932
7	1230·5963	124·3550
8	1235·7833	124·6168
9	1240·9811	124·8786
10	1246·1898	125·1404
11	1251·4094	125·4022
40*ft.*	1256·6400	125·6640
1	1261·8814	125·9258
2	1267·1338	126·1876
3	1272·3971	126·4494
4	1277·6712	126·7112
5	1282·9563	126·9730
6	1288·2523	127·2348
7	1293·5592	127·4966
8	1298·8770	127·7584
9	1304·2058	128·0202
10	1309·5454	128·2820
11	1314·8959	128·5438

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
	Feet.	Feet.		Feet.	Feet.		Feet.	Feet.
41*ft*.	1320·2574	128·8056	44*ft*.	1520·5344	138·2304	47*ft*.	1734·9486	147·6552
1	1325·6297	129·0674	1	1526·2994	138·4922	1	1741·1063	147·9170
2	1331·0130	129·3292	2	1532·0754	138·7540	2	1747·2750	148·1788
3	1336·4072	129·5910	3	1537·8623	139·0158	3	1753·4546	148·4406
4	1341·8123	129·8528	4	1543·6600	139·2776	4	1759·6451	148·7024
5	1347·2282	130·1146	5	1549·4687	139·5394	5	1765·8464	148·9642
6	1352·6551	130·3764	6	1555·2883	139·8012	6	1772·0587	149·2260
7	1358·0929	130·6382	7	1561·1188	140·0630	7	1778·2819	149·4878
8	1363·5416	130·9000	8	1566·9603	140·3248	8	1784·5160	149·7496
9	1369·0013	131·1618	9	1572·8126	140·5866	9	1790·7611	150·0114
10	1374·4718	131·4236	10	1578·6756	140·8484	10	1797·0170	150·2732
11	1379·9532	131·6854	11	1584·5499	141·1102	11	1803·2838	150·5350
42*ft*.	1385·4456	131·9472	45*ft*.	1590·4350	141·3720	48*ft*.	1809·5616	150·7968
1	1390·9488	132·2090	1	1596·3309	141·6338	1	1815·8502	151·0586
2	1396·4630	132·4708	2	1602·2378	141·8956	2	1822·1498	151·3204
3	1401·9881	132·7326	3	1608·1556	142·1574	3	1828·4603	151·5822
4	1407·5241	132·9944	4	1614·0843	142·4192	4	1834·7817	151·8440
5	1413·0709	133·2562	5	1620·0238	142·6810	5	1841·1139	152·1058
6	1418·6287	133·5180	6	1625·9743	142·9428	6	1847·4571	152·3676
7	1424·1974	133·7798	7	1631·9357	143·2046	7	1853·8112	152·6294
8	1429·7770	134·0416	8	1637·9081	143·4664	8	1860·1763	152·8912
9	1435·3676	134·3034	9	1643·8913	143·7282	8	1866·5522	153·1530
10	1440·9690	134·5652	10	1649·8854	143·9900	10	1872·9390	153·4148
11	1446·5813	134·8270	11	1655·8904	144·2518	11	1879·3367	153·6766
43*ft*.	1452·2046	135·0888	46*ft*.	1661·9064	144·5136	49*ft*.	1885·7454	153·9384
1	1457·8387	135·3506	1	1667·9332	144·7754	1	1892·1649	154·2002
2	1463·4838	135·6124	2	1673·9710	145·0372	2	1898·5954	154·4620
3	1469·1398	135·8742	3	1680·0197	145·2990	3	1905·0368	154·7238
4	1474·8066	136·1360	4	1686·0792	145·5608	4	1911·4897	154·9856
5	1480·4844	136·3978	5	1692·1497	145·8226	5	1917·9522	155·2474
6	1486·1731	136·6596	6	1698·2311	146·0844	6	1924·4263	155·5092
7	1491·8717	136·9214	7	1704·3234	146·3462	7	1930·9113	155·7710
8	1497·5833	137·1832	8	1710·4267	146·6080	8	1937·4073	156·0328
9	1503·3047	137·4450	9	1716·5408	146·8698	9	1943·9142	156·2946
10	1509·0370	137·7068	10	1722·6658	147·1316	10	1950·4318	156·5564
11	1514·7802	137·9686	11	1728·8017	147·3934	11	1956·9604	156·8182
						50*ft*.	1963·5000	157·0800

Areas and Circumferences of Circles (either inches or feet, from $\frac{1}{100}$ to 100.

Advancing by 1-100ths, 5-100ths, and 1-10ths.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
			.40	.125664	1.25664	.80	.502656	2.51328
.01	.000078	.031416	.41	.132025	1.28805	.81	.515300	2.54469
.02	.000314	.062832	.42	.138544	1.31947	.82	.528102	2.57611
.03	.000706	.094248	.43	.145220	1.35088	.83	.541062	2.60752
.04	.001256	.125664	.44	.152053	1.38230	.84	.554178	2.63894
.05	.001963	.157080	.45	.159043	1.41372	.85	.567451	2.67036
.06	.002827	.188496	.46	.166190	1.44513	.86	.580881	2.70177
.07	.003848	.219912	.47	.173494	1.47655	.87	.594469	2.73319
.08	.005026	.251328	.48	.180956	1.50796	.88	.608213	2.76460
.09	.006361	.282744	.49	.188574	1.53938	.89	.622115	2.79602
.10	.007854	.314160	.50	.196350	1.57080	.90	.636174	2.82744
.11	.009503	.345576	.51	.204282	1.60221	.91	.650389	2.85885
.12	.011309	.376992	.52	.212372	1.63363	.92	.664762	2.89027
.13	.013273	.408408	.53	.220618	1.66504	.93	.679292	2.92168
.14	.015393	.439824	.54	.229022	1.69646	.94	.693979	2.95310
.15	.017671	.471240	.55	.237583	1.72788	.95	.708823	2.98452
.16	.020106	.502656	.56	.246301	1.75929	.96	.723824	3.01593
.17	.022698	.534072	.57	.255176	1.79071	.97	.738982	3.04735
.18	.025446	.565488	.58	.264208	1.82212	.98	.754298	3.07876
.19	.028352	.596904	.59	.273397	1.85354	.99	.769770	3.11018
.20	.031416	.628320	.60	.282744	1.88496	1.	.7854	3.1416
.21	.034636	.659736	.61	.292247	1.91637	.05	.8659	3.2986
.22	.038013	.691152	.62	.301907	1.94779	.10	.9503	3.4558
.23	.041547	.722568	.63	.311725	1.97920	.15	1.0386	3.6129
.24	.045239	.753984	.64	.321699	2.01062	.20	1.1310	3.7699
.25	.049087	.785400	.65	.331831	2.04204	.25	1.2272	3.9270
.26	.053093	.816816	.66	.342120	2.07345	.30	1.3273	4.0841
.27	.057255	.848232	.67	.352566	2.10487	.35	1.4313	4.2412
.28	.061575	.879648	.68	.363168	2.13628	.40	1.5394	4.3982
.29	.066052	.911064	.69	.373928	2.16770	.45	1.6513	4.5553
.30	.070686	.942480	.70	.384846	2.19912	.50	1.7671	4.7124
.31	.075476	.973896	.71	.395920	2.22053	.55	1.8869	4.8695
.32	.080424	1.005312	.72	.407151	2.26195	.60	2.0106	5.0266
.33	.085530	1.036728	.73	.418539	2.29336	.65	2.1382	5.1837
.34	.090792	1.068144	.74	.430085	2.32478	.70	2.2698	5.3407
.35	.096211	1.099560	.75	.441787	2.35620	.75	2.4053	5.4978
.36	.101787	1.130976	.76	.453647	2.38761	.80	2.5447	5.6549
.37	.107521	1.162392	.77	.465663	2.41903	.85	2.6880	5.8119
.38	.113411	1.193808	.78	.477837	2.45044	.90	2.8353	5.9690
.39	.119459	1.225224	.79	.490168	2.48186	.95	2.9865	6.1261

Digitized by Google

AREA AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
2.	3.1416	6.2832	4.	12.5664	12.5664	8.	50.2656	25.1328
.05	3.3006	6.4403	.1	13.2026	12.8806	.1	51.5301	25.4470
.10	3.4636	6.5974	.2	13.8545	13.1947	.2	52.8103	25.7611
.15	3.6305	6.7544	.3	14.5220	13.5089	.3	54.1062	26.0753
.20	3.8013	6.9115	.4	15.2053	13.8230	.4	55.4178	26.3894
.25	3.9761	7.0686	.5	15.9043	14.1372	.5	56.7451	26.7036
.30	4.1548	7.2257	.6	16.6191	14.4514	.6	58.0882	27.0178
.35	4.3374	7.3827	.7	17.3495	14.7655	.7	59.4469	27.3319
.40	4.5239	7.5398	.8	18.0956	15.0797	.8	60.8214	27.6461
.45	4.7144	7.6969	.9	18.8575	15.3938	.9	62.2115	27.9602
.50	4.9087	7.8540	5.	19.6350	15.7080	9.	63.6174	28.2744
.55	5.1071	8.0111	.1	20.4283	16.0222	.1	65.0390	28.5886
.60	5.3093	8.1682	.2	21.2372	16.3363	.2	66.4763	28.9027
.65	5.5155	8.3252	.3	22.0619	16.6505	.3	67.9292	29.2169
.70	5.7256	8.4823	.4	22.9023	16.9646	.4	69.3979	29.5310
.75	5.9396	8.6394	.5	23.7583	17.2788	.5	70.8823	29.8452
.80	6.1575	8.7965	.6	24.6301	17.5930	.6	72.3825	30.1594
.85	6.3794	8.9536	.7	25.5176	17.9071	.7	73.8983	30.4735
.90	6.6052	9.1106	.8	26.4209	18.2213	.8	75.4298	30.7877
.95	6.8349	9.2677	.9	27.3398	18.5354	.9	76.9771	31.1018
3.	7.0686	9.4248	6.	28.2744	18.8496	10.	78.5400	31.4160
.05	7.3062	9.5819	.1	29.2247	19.1638	.1	80.1187	31.7302
.10	7.5477	9.7390	.2	30.1908	19.4779	.2	81.7130	32.0443
.15	7.7931	9.8960	.3	31.1725	19.7921	.3	83.3231	32.3585
.20	8.0425	10.0531	.4	32.1700	20.1062	.4	84.9489	32.6726
.25	8.2958	10.2102	.5	33.1831	20.4204	.5	86.5903	32.9868
.30	8.5530	10.3673	.6	34.2120	20.7346	.6	88.2475	33.3010
.35	8.8142	10.5243	.7	35.2566	21.0487	.7	89.9204	33.6151
.40	9.0792	10.6814	.8	36.3169	21.3629	.8	91.6091	33.9293
.45	9.3482	10.8385	.9	37.3929	21.6770	.9	93.3134	34.2434
.50	9.6211	10.9956	7.	38.4846	21.9912	11.	95.0334	34.5576
.55	9.8980	11.1527	.1	39.5920	22.3054	.1	96.7691	34.8718
.60	10.1788	11.3098	.2	40.7151	22.6195	.2	98.5206	35.1859
.65	10.4635	11.4668	.3	41.8540	22.9337	.3	100.2877	35.5001
.70	10.7521	11.6239	.4	43.0085	23.2478	.4	102.0706	35.8142
.75	11.0447	11.7810	.5	44.1 87	23.5620	.5	103.8691	36.1284
.80	11.3412	11.9381	.6	45.3647	23.8762	.6	105.6834	36.4426
.85	11.6416	12.0951	.7	46.5664	24.1903	.7	107.5134	36.7567
.90	11.9459	12.2522	.8	47.7837	24.5045	.8	109.3591	37.0709
.95	12.2542	12.4093	.9	49.0168	24.8186	.9	111.2205	37.3850

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
12·	113·0976	37·6992	16·	201·0624	50·2656	20·	314·1600	62·8320
·1	114·9904	38·0134	·1	203·5835	50·5797	·1	317·3094	63·1462
·2	116·8989	38·3275	·2	206·1204	50·8939	·2	320·4746	63·4603
·3	118·8232	38·6417	·3	208·6729	51·2081	·3	323·6555	63·7745
·4	120·7631	38·9558	·4	211·2412	51·5222	·4	326·8521	64·0886
·5	122·7187	39·2700	·5	213·8251	51·8364	·5	330·0643	64·4028
·6	124·6901	39·5842	·6	216·4248	52·1505	·6	333·2923	64·7170
·7	126·6772	39·8983	·7	219·0402	52·4647	·7	336·5360	65·0311
·8	128·6799	40·2125	·8	221·6713	52·7789	·8	339·7955	65·3453
·9	130·6984	40·5266	·9	224·3181	53·0930	·9	343·0706	65·6594
13·	132·7326	40·8408	17·	226·9806	53·4072	21·	346·3614	65·9736
·1	134·7825	41·1550	·1	229·6588	53·7214	·1	349·6678	66·2878
·2	136·8481	41·4691	·2	232·3527	54·0355	·2	352·9902	66·6019
·3	138·9294	41·7833	·3	235·0624	54·3497	·3	356·3281	66·9161
·4	141·0264	42·0974	·4	237·7877	54·6638	·4	359·6818	67·2302
·5	143·1391	42·4116	·5	240·5287	54·9780	·5	363·0511	67·5444
·6	145·2676	42·7258	·6	243·2855	55·2922	·6	366·4362	67·8586
·7	147·4117	43·0399	·7	246·0580	55·6063	·7	369·8370	68·1727
·8	149·5716	43·3541	·8	248·8461	55·9205	·8	373·2535	68·4869
·9	151·7471	43·6682	·9	251·6500	56·2346	·9	376·6857	68·8010
14·	153·9384	43·9824	18·	254·4696	56·5488	22·	380·1336	69·1152
·1	156·1454	44·2966	·1	257·3049	56·8630	·1	383·5972	69·4294
·2	158·3681	44·6107	·2	260·1559	57·1771	·2	387·0765	69·7435
·3	160·6064	44·9249	·3	263·0226	57·4913	·3	390·5716	70·0577
·4	162·8605	45·2390	·4	265·9050	57·8054	·4	394·0823	70·3718
·5	165·1303	45·5532	·5	268·8031	58·1196	·5	397·6087	70·6860
·6	167·4159	45·8674	·6	271·7170	58·4338	·6	401·1509	71·0002
·7	169·7171	46·1815	·7	274·6465	58·7479	·7	404·7088	71·3143
·8	172·0340	46·4957	·8	277·5918	59·0621	·8	408·2823	71·6285
·9	174·3667	46·8098	·9	280·5527	59·3762	·9	411·8716	71·9426
15·	176·7150	47·1240	19·	283·5294	59·6904	23·	415·4766	72·2568
·1	179·0791	47·4382	·1	286·5218	60·0046	·1	419·0973	72·5710
·2	181·4588	47·7523	·2	289·5299	60·3187	·2	422·7337	72·8851
·3	183·8543	48·0665	·3	292·5536	60·6329	·3	426·3858	73·1993
·4	186·2655	48·3806	·4	295·5931	60·9470	·4	430·0536	73·5134
·5	188·6924	48·6948	·5	298·6483	61·2612	·5	433·7371	73·8276
·6	191·1349	49·0090	·6	301·7193	61·5754	·6	437·4364	74·1418
·7	193·5932	49·3231	·7	304·8060	61·8895	·7	441·1513	74·4559
·8	196·0673	49·6373	·8	307·9082	62·2037	·8	444·8820	74·7701
·9	198·5570	49·9514	·9	311·0263	62·5178	·9	448·6283	75·0842

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
24·	452·3904	75·3984	28·	615·7536	87.9648	32·	804·2496	100·5312
·1	456·1682	75·7126	·1	620·1597	88.2790	·1	809·2840	100·8454
·2	459·9617	76·0267	·2	624·5815	88·5931	·2	814·3341	101·1595
·3	463·7708	76·3409	·3	629·0190	88·9073	·3	819·4000	101·4737
·4	467·5957	76·6550	·4	633·4722	89·2214	·4	824·4815	101·7878
·5	471·4363	76·9692	·5	637·9411	89·5356	·5	829·5787	102·1020
·6	475·2927	77·2834	·6	642·4258	89·8498	·6	834·6917	102·4162
·7	479·1647	77·5975	·7	646·9261	90·1639	·7	839·8204	102·7303
·8	483·0524	77·9117	·8	651·4422	90·4781	·8	844·9647	103·0445
·9	486·9559	78·2258	·9	655·9739	90·7922	·9	850·1248	103·3586
25·	490·8750	78·5400	29·	660·5214	91·1064	33·	855·3006	103·6728
·1	494·8099	78·8542	·1	665·0846	91·4206	·1	860·4921	103·9870
·2	498·7604	79·1683	·2	669·6635	91·7347	·2	865·6993	104·3011
·3	502·7267	79·4825	·3	674·2580	92·0489	·3	870·9222	104·6153
·4	506·7087	79·7966	·4	678·8683	92·3630	·4	876·1608	104·9294
·5	510·7063	80·1108	·5	683·4943	92·6772	·5	881·4151	105·2436
·6	514·7196	80·4250	·6	688·1361	92·9914	·6	886·6852	105·5578
·7	518·7488	80·7391	·7	692·7935	93·3055	·7	891·9709	105·8719
·8	522·7937	81·0533	·8	697·4666	93·6197	·8	897·2724	106·1861
·9	526·8542	81·3674	·9	702·1555	93·9338	·9	902·5895	106·5002
26·	530·9304	81·6816	30·	706·8600	94·2480	34·	907·9224	106·8144
·1	535·0223	81·9958	·1	711·5803	94·5622	·1	913·2710	107·1286
·2	539·1300	82·3099	·2	716·3162	94·8763	·2	918·6353	107·4427
·3	543·2533	82·6241	·3	721·0679	95·1905	·3	924·0152	107·7569
·4	547·3924	82·9382	·4	725·8353	95·5046	·4	929·4109	108·0710
·5	551·5471	83·2524	·5	730·6183	95·8188	·5	934·8223	108·3852
·6	555·7176	83·5666	·6	735·4171	96·1330	·6	940·2495	108·6994
·7	559·9038	83·8807	·7	740·2316	96·4471	·7	945·6923	109·0135
·8	564·1057	84·1949	·8	745·0619	96·7613	·8	951·1508	109·3277
·9	568·3233	84·5090	·9	749·9078	97·0754	·9	956·6251	109·6418
27·	572·5566	84·8232	31·	754·7694	97·3896	35·	962·1150	109·9560
·1	576·8056	85·1374	·1	759·6467	97·7038	·1	967·6207	110·2702
·2	581·0703	85·4515	·2	764·5398	98·0179	·2	973·1420	110·5843
·3	585·3508	85·7657	·3	769·4485	98·3321	·3	978·6791	110·8985
·4	589·6469	86·0798	·4	774·3730	98·6462	·4	984·2319	111·2126
·5	593·9587	86·3940	·5	779·3131	98·9604	·5	989·8003	111·5268
·6	598·2863	86·7082	·6	784·2690	99·2746	·6	995·3845	111·8410
·7	602·6296	87·0223	·7	789·2406	99·5887	·7	1000·9844	112·1551
·8	606·9885	87·3365	·8	794·2279	99·9029	·8	1006·6001	112·4693
·9	611·3632	87·6506	·9	799·2309	100·2170	·9	1012·2314	112·7834

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

ia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
·	1017·8784	113·0976	40·	1256·6400	125·6640	44·	1520·5344	138·2304
·1	1023·5411	113·4118	·1	1262·9311	125·9782	·1	1527·4538	138·5446
·2	1029·2196	113·7259	·2	1269·2378	126·2923	·2	1534·3889	138·8587
·3	1034·9137	114·0401	·3	1275·5603	126·6065	·3	1541·3396	139·1729
·4	1040·6236	114·3542	·4	1281·8985	126·9206	·4	1548·3061	139·4870
·5	1046·3491	114·6684	·5	1288·2523	127·2348	·5	1555·2883	139·8012
·6	1052·0904	114·9826	·6	1294·6219	127·5490	·6	1562·2863	140·1154
·7	1057·8474	115·2967	·7	1301·0072	127·8631	·7	1569·2999	140·4295
·8	1063·6201	115·6109	·8	1307·4083	128·1773	·8	1576·3292	140·7437
·9	1069·4085	115·9250	·9	1313·8250	128·4914	·9	1583·3743	141·0578
·'	1075·2126	116·2392	41·	1320·2574	128·8056	45·	1590·4350	141·3720
·1	1081·0324	116·5534	·1	1326·7055	129·1198	·1	1597·5115	141·6862
·2	1086·8679	116·8675	·2	1333·1694	129·4339	·2	1604·6036	142·0003
·3	1092·7192	117·1817	·3	1339·6489	129·7481	·3	1611·7115	142·3145
·4	1098·5861	117·4958	·4	1346·1442	130·0622	·4	1618·8351	142·6286
·5	1104·4687	117·8100	·5	1352·6551	130·3764	·5	1625·9743	142·9428
·6	1110·3671	118·1242	·6	1359·1818	130·6906	·6	1633·1293	143·2570
·7	1116·2812	118·4383	·7	1365·7242	131·0047	·7	1640·3000	143·5711
·8	1122·2109	118·7525	·8	1372·2823	131·3189	·8	1647·4865	143·8853
·9	1128·1564	119·0666	·9	1378·8561	131·6330	·9	1654·6886	144·1994
8·	1134·1176	119·3808	42·	1385·4456	131·9472	46·	1661·9064	144·5136
·1	1140·0945	119·6950	·1	1392·0508	132·2614	·1	1669·1399	144·8278
·2	1146·0871	120·0091	·2	1398·6717	132·5755	·2	1676·3892	145·1419
·3	1152·0954	120·3233	·3	1405·3084	132·8897	·3	1683·6541	145·4561
·4	1158·1194	120·6374	·4	1411·9607	133·2038	·4	1690·9348	145·7702
·5	1164·1591	120·9516	·5	1418·6287	133·5180	·5	1698·2311	146·0844
·6	1170·2146	121·2658	·6	1425·3125	133·8322	·6	1705·5432	146·3986
·7	1176·2857	121·5799	·7	1432·0120	134·1463	·7	1712·8710	146·7127
·8	1182·3726	121·8941	·8	1438·7271	134·4605	·8	1720·2145	147·0269
·9	1188·4751	122·2082	·9	1445·4580	134·7746	·9	1727·5737	147·3410
·	1194·5934	122·5224	43·	1452·2046	135·0888	47·	1734·9486	147·6552
·1	1200·7274	122·8366	·1	1458·9669	135·4030	·1	1742·3392	147·9694
·2	1206·8771	123·1507	·2	1465·7449	135·7171	·2	1749·7455	148·2835
·3	1213·0424	123·4649	·3	1472·5386	136·0313	·3	1757·1676	148·5977
·4	1219·2235	123·7790	·4	1479·3480	136·3454	·4	1764·6053	148·9118
·5	1225·4203	124·0932	·5	1486·1731	136·6596	·5	1772·0587	149·2260
·6	1231·6329	124·4074	·6	1493·0140	136·9738	·6	1779·5279	149·5402
·7	1237·8611	124·7215	·7	1499·8705	137·2879	·7	1787·0128	149·8543
·8	1244·1050	125·0357	·8	1506·7428	137·6021	·8	1794·5133	150·1685
·9	1250·3647	125·3498	·9	1513·6307	137·9162	·9	1802·0296	150·4826

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
48·	1809·5616	150·7968	52·	2123·7216	163·3632	56·	2463·0144	175·929
·1	1817·1093	151·1110	·1	2131·8976	163·6774	·1	2471·8187	176·243
·2	1824·6727	151·4251	·2	2140·0893	163·9915	·2	2480·6388	176·557
·3	1832·2518	151·7393	·3	2148·2968	164·3057	·3	2489·4745	176·872
·4	1839·8466	152·0534	·4	2156·5199	164·6198	·4	2498·3260	177·186
·5	1847·4571	152·3676	·5	2164·7587	164·9340	·5	2507·1931	177·500
·6	1855·0834	152·6818	·6	2173·0133	165·2482	·6	2516·0760	177·814
·7	1862·7253	152·9959	·7	2181·2836	165·5623	·7	2524·9736	178·128
·8	1870·3830	153·3101	·8	2189·5695	165·8765	·8	2533·8889	178·442
·9	1878·0563	153·6242	·9	2197·8712	166·1906	·9	2542·8189	178·757
49·	1885·7454	153·9384	53·	2206·1886	166·5048	57·	2551·7646	179·071
·1	1893·4502	154·2526	·1	2214·5217	166·8190	·1	2560·7260	179·385
·2	1901·1707	154·5667	·2	2222·8705	167·1331	·2	2569·7031	179·699
·3	1908·9068	154·8809	·3	2231·2350	167·4473	·3	2578·6960	180·013
·4	1916·6587	155·1950	·4	2239·6152	167·7614	·4	2587·7045	180·327
·5	1924·4263	155·5092	·5	2248·0111	168·0756	·5	2596·7287	180·642
·6	1932·2097	155·8234	·6	2256·4228	168·3898	·6	2605·7687	180·956
·7	1940·0087	156·1375	·7	2264·8501	168·7039	·7	2614·8244	181·270
·8	1947·8234	156·4517	·8	2273·2932	169·0181	·8	2623·8957	181·584
·9	1955·6539	156·7658	·9	2281·7519	169·3322	·9	2632·9828	181·898
50·	1963·5000	157·0800	54·	2290·2264	169·6464	58·	2642·0856	182·212
·1	1971·3619	157·3942	·1	2298·7166	169·9606	·1	2651·2041	182·527
·2	1979·2394	157·7083	·2	2307·2225	170·2747	·2	2660·3383	182·841
·3	1987·1327	158·0225	·3	2315·7440	170·5889	·3	2669·4882	183·155
·4	1995·0417	158·3366	·4	2324·2813	170·9030	·4	2678·6538	183·469
·5	2002·9663	158·6509	·5	2332·8343	171·2172	·5	2687·8351	183·783
·6	2010·9067	158·9650	·6	2341·4031	171·5314	·6	2697·0322	184·097
·7	2018·8628	159·2791	·7	2349·9875	171·8455	·7	2706·2449	184·411
·8	2026·8347	159·5933	·8	2358·5876	172·1597	·8	2715·4734	184·726
·9	2034·8222	159·9074	·9	2367·2035	172·4738	·9	2724·7175	185·040
51·	2042·8254	160·2216	55·	2375·8350	172·7880	59·	2733·9774	185·354
·1	2050·8443	160·5358	·1	2384·4823	173·1022	·1	2743·2530	185·668
·2	2058·8790	160·8499	·2	2393·1452	173·4163	·2	2752·5443	185·98
·3	2066·9293	161·1641	·3	2401·8239	173·7305	·3	2761·8512	186·29
·4	2074·9954	161·4782	·4	2410·5183	174·0446	·4	2771·1739	186·611
·5	2083·0771	161·7924	·5	2419·2283	174·3588	·5	2780·5123	186·92
·6	2091·1746	162·1066	·6	2427·9541	174·6730	·6	2789·8665	187·23
·7	2099·2878	162·4207	·7	2436·6957	174·9871	·7	2799·2363	187·55
·8	2107·4167	162·7349	·8	2445·4529	175·3013	·8	2808·6218	187·86
·9	2115·5613	163·0490	·9	2454·2258	175·6154	·9	2818·0231	188·18

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
60·	2827·4400	188·4960	64·	3216·9984	201·0624	68·	3631·6896	213·6288
·1	2836·8727	188·8102	·1	3227·0594	201·3766	·1	3642·3789	213·9430
·2	2846·3210	189·1243	·2	3237·1361	201·6907	·2	3653·0839	214·2571
·3	2855·7851	189·4385	·3	3247·2284	202·0049	·3	3663·8050	214·5713
·4	2865·2649	189·7526	·4	3257·3365	202·3190	·4	3674·5410	214·8854
·5	2874·7603	190·0668	·5	3267·4603	202·6332	·5	3685·2931	215·1996
·6	2884·2715	190·3810	·6	3277·5999	202·9474	·6	3696·0610	215·5138
·7	2893·7984	190·6951	·7	3287·7551	203·2615	·7	3706·8445	215·8279
·8	2903·3411	191·0093	·8	3297·9261	203·5757	·8	3717·6438	216·1421
·9	2912·8994	191·3234	·9	3308·1127	203·8898	·9	3728·4587	216·4562
61·	2922·4734	191·6376	65·	3318·3150	204·2040	69·	3739·2894	216·7704
·1	2932·0631	191·9518	·1	3328·5331	204·5182	·1	3750·1358	217·0846
·2	2941·6686	192·2659	·2	3338·7668	204·8323	·2	3760·9979	217·3987
·3	2951·2897	192·5801	·3	3349·0163	205·1465	·3	3771·8756	217·7129
·4	2960·9266	192·8942	·4	3359·2815	205·4606	·4	3782·7691	218·0270
·5	2970·5791	193·2084	·5	3369·5623	205·7748	·5	3793·6783	218·3412
·6	2980·2474	193·5226	·6	3379·8589	206·0890	·6	3804·6033	218·6554
·7	2989·9314	193·8367	·7	3390·1712	206·4031	·7	3815·5439	218·9695
·8	2999·6311	194·1509	·8	3400·4993	206·7173	·8	3826·5002	219·2837
·9	3009·3465	194·4650	·9	3410·8430	207·0314	·9	3837·4722	219·5978
62·	3019·0776	194·7792	66·	3421·2024	207·3456	70·	3848·4600	219·9120
·1	3028·8244	195·0934	·1	3431·5775	207·6598	·1	3859·4635	220·2262
·2	3038·5869	195·4075	·2	3441·9684	207·9739	·2	3870·4826	220·5403
·3	3048·3652	195·7217	·3	3452·3749	208·2881	·3	3881·5175	220·8545
·4	3058·1591	196·0358	·4	3462·7972	208·6022	·4	3892·5681	221·1686
·5	3067·9687	196·3500	·5	3473·2351	208·9164	·5	3903·6343	221·4828
·6	3077·7941	196·6642	·6	3483·6888	209·2306	·6	3914·7163	221·7970
·7	3087·6341	196·9783	·7	3494·1582	209·5447	·7	3925·8140	222·1111
·8	3097·4919	197·2925	·8	3504·6433	209·8589	·8	3936·9275	222·4253
·9	3107·3644	197·6066	·9	3515·1441	210·1730	·9	3948·9566	222·7394
63·	3117·2526	197·9208	67·	3525·6606	210·4872	71·	3959·2014	223·0536
·1	3127·1565	198·2350	·1	3536·1928	210·8014	·1	3970·3619	223·3678
·2	3137·0761	198·5491	·2	3546·7407	211·1155	·2	3981·5382	223·6819
·3	3147·0114	198·8633	·3	3557·3044	211·4297	·3	3992·7301	223·9961
·4	3156·9624	199·1774	·4	3567·8837	211·7438	·4	4003·9378	224·3102
·5	3166·9291	199·4916	·5	3578·4787	212·0580	·5	4015·1611	224·6244
·6	3176·9116	199·8058	·6	3589·0895	212·3722	·6	4026·4002	224·9386
·7	3186·9097	200·1199	·7	3599·7160	212·6863	·7	4037·6550	225·2527
·8	3196·9236	200·4341	·8	3610·3581	213·0005	·8	4048·9255	225·5669
·9	3206·9531	200·7482	·9	3621·0160	213·3146	·9	4060·2117	225·8810

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
72·	4071·5136	226·1952	76·	4536·4704	238·7616	80·	5026·5600	251·3280
·1	4082·8312	226·5094	·1	4548·4163	239·0758	·1	5039·1343	251·6422
·2	4094·1645	226·8235	·2	4560·3780	239·3899	·2	5051·7242	251·9563
·3	4105·5136	227·1377	·3	4572·3553	239·7041	·3	5064·3299	252·2705
·4	4116·8783	227·4518	·4	4584·3484	240·0182	·4	5076·9513	252·5846
·5	4128·2587	227·7660	·5	4596·3571	240·3324	·5	5089·5883	252·8988
·6	4139·6550	228·0802	·6	4608·3816	240·6466	·6	5102·2411	253·2130
·7	4151·0668	228·3943	·7	4620·4218	240·9607	·7	5114·9096	253·5271
·8	4162·4943	228·7085	·8	4632·4777	241·2749	·8	5127·5939	253·8413
·9	4173·9376	229·0226	·9	4644·5493	241·5890	·9	5140·2938	254·1554
73·	4185·3966	229·3368	77·	4656·6366	241·9032	81·	5153·0094	254·4696
·1	4196·8713	229·6510	·1	4668·7396	242·2174	·1	5165·7407	254·7838
·2	4208·3617	229·9651	·2	4680·8583	242·5315	·2	5178·4878	255·0979
·3	4219·8678	230·2793	·3	4692·9928	242·8457	·3	5191·2505	255·4121
·4	4231·3896	230·5934	·4	4705·1429	243·1598	·4	5204·0289	255·7262
·5	4242·9271	230·9076	·5	4717·3087	243·4740	·5	5216·8231	256·0404
·6	4254·4804	231·2218	·6	4729·4903	243·7882	·6	5229·6330	256·3546
·7	4266·0493	231·5359	·7	4741·6876	244·1023	·7	5242·4586	256·6687
·8	4277·6340	231·8501	·8	4753·9005	244·4165	·8	5255·2999	256·9829
·9	4289·2343	232·1642	·9	4766·1292	244·7306	·9	5268·1569	257·2970
74·	4300·8504	232·4784	78·	4778·3736	245·0448	82·	5281·0296	257·6112
·1	4312·4822	232·7926	·1	4790·6337	245·3590	·1	5293·9180	257·9254
·2	4324·1297	233·1067	·2	4802·9095	245·6731	·2	5306·8221	258·2395
·3	4335·7928	233·4209	·3	4815·2010	245·9873	·3	5319·7420	258·5537
·4	4347·4717	233·7350	·4	4827·5082	246·3014	·4	5332·6775	258·8678
·5	4359·1663	234·0492	·5	4839·8311	246·6156	·5	5345·6287	259·1820
·6	4370·8767	234·3634	·6	4852·1698	246·9298	·6	5358·5957	259·4962
·7	4382·6027	234·6775	·7	4864·5241	247·2439	·7	5371·5784	259·8103
·8	4394·3444	234·9917	·8	4876·8942	247·5581	·8	5384·5767	260·1245
·9	4406·1019	235·3058	·9	4889·2799	247·8722	·9	5397·5908	260·4386
75·	4417·8750	235·6200	79·	4901·6814	248·1864	83·	5410·6206	260·7528
·1	4429·6639	235·9342	·1	4914·0986	248·5006	·1	5423·6661	261·0670
·2	4441·4684	236·2483	·2	4926·5315	248·8147	·2	5436·7273	261·3811
·3	4453·2887	236·5625	·3	4938·9800	249·1289	·3	5449·8042	261·6953
·4	4465·1247	236·8766	·4	4951·4443	249·4430	·4	5462·8968	262·0094
·5	4476·9763	237·1908	·5	4963·9243	249·7572	·5	5476·0051	262·3236
·6	4488·8437	237·5050	·6	4976·4201	250·0714	·6	5489·1292	262·6378
·7	4500·7268	237·8191	·7	4988·9315	250·3855	·7	5502·2689	262·9519
·8	4512·6257	238·1333	·8	5001·4586	250·6997	·8	5515·4244	263·2661
·9	4524·5402	238·4474	·9	5014·0015	251·0138	·9	5528·5955	263·5802

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
84·	5541·7824	263·8944	88·	6082·1376	276·4608	92·	6647·6256	289·0272
·1	5554·9850	264·2086	·1	6095·9685	276·7750	·1	6662·0848	289·3414
·2	5568·2033	264·5227	·2	6109·8151	277·0891	·2	6676·5598	289·6555
·3	5581·4372	264·8369	·3	6123·6774	277·4033	·3	6691·0504	289·9697
·4	5594·6869	265·1510	·4	6137·5554	277·7174	·4	6705·5567	290·2838
·5	5607·9523	265·4652	·5	6151·4491	278·0316	·5	6720·0787	290·5980
·6	5621·2335	265·7794	·6	6165·3586	278·3458	·6	6734·6165	290·9121
·7	5634·5303	266·0935	·7	6179·2837	278·6599	·7	6749·1700	291·2263
·8	5647·8428	266·4077	·8	6193·2246	278·9741	·8	6763·7391	291·5405
·9	5661·1711	266·7218	·9	6207·1811	279·2882	·9	6778·3240	291·8546
85·	5674·5150	267·0360	89·	6221·1534	279·6024	93·	6792·9246	292·1688
·1	5687·8747	267·3502	·1	6235·1414	279·9166	·1	6807·5409	292·4830
·2	5701·2500	267·6643	·2	6249·1451	280·2307	·2	6822·1729	292·7971
·3	5714·6411	267·9785	·3	6263·1644	280·5449	·3	6836·8206	293·1113
·4	5728·0479	268·2926	·4	6277·1995	280·8590	·4	6851·4840	293·4254
·5	5741·4703	268·6068	·5	6291·2503	281·1732	·5	6866·1631	293·7396
·6	5754·9085	268·9210	·6	6305·3169	281·4874	·6	6880·8580	294·0538
·7	5768·3624	269·2351	·7	6319·3991	281·8015	·7	6895·5685	294·3679
·8	5781·8321	269·5493	·8	6333·4970	282·1157	·8	6910·2948	294·6821
·9	5795·3174	269·8634	·9	6347·6107	282·4298	·9	6925·0367	294·9962
86·	5808·8184	270·1776	90·	6361·7400	282·7440	94·	6939·7944	295·3104
·1	5822·3351	270·4918	·1	6375·8851	283·0582	·1	6954·5678	295·6246
·2	5835·8676	270·8059	·2	6390·0458	283·3723	·2	6969·3569	295·9387
·3	5849·4157	271·1201	·3	6404·2223	283·6865	·3	6984·1616	296·2529
·4	5862·9796	271·4342	·4	6418·4144	284·0006	·4	6998·9821	296·5670
·5	5876·5591	271·7484	·5	6432·6223	284·3148	·5	7013·8183	296·8812
·6	5890·1544	272·0626	·6	6446·8459	284·6290	·6	7028·6703	297·1954
·7	5903·7654	272·3767	·7	6461·0852	284·9431	·7	7043·5379	297·5095
·8	5917·3921	272·6909	·8	6475·3403	285·2573	·8	7058·4212	297·8237
·9	5931·0345	273·0050	·9	6489·6110	285·5714	·9	7073·3203	298·1378
87·	5944·6926	273·3192	91·	6503·8974	285·8856	95·	7088·2350	298·4520
·1	5958·3644	273·6334	·1	6518·1995	286·1998	·1	7103·1655	298·7662
·2	5972·0559	273·9475	·2	6532·5174	286·5139	·2	7118·1116	299·0803
·3	5985·7612	274·2617	·3	6546·8509	286·8281	·3	7133·0735	299·3945
·4	5999·4821	274·5758	·4	6561·2002	287·1422	·4	7148·0511	299·7086
·6	6013·2187	274·8900	·5	6575·5651	287·4564	·5	7163·0443	300·0228
·6	6026·9711	275·2042	·6	6589·9458	287·7706	·6	7178·0533	300·3370
·7	6040·7392	275·5183	·7	6604·3422	288·0847	·7	7193·0780	300·6511
·8	6054·5229	275·8325	·8	6618·7543	288·3989	·8	7208·1185	300·9653
·9	6068·3224	276·1466	·9	6633·1821	288·7130	·9	7223·1746	301·2794

Digitized by Google

AREAS AND CIRCUMFERENCES OF CIRCLES.

Dia.	Area.	Circum.	Dia.	Area.	Circum.	Dia.	Area.	Circum.
96·	7238·2464	301·5936	·4	7450·9013	305·9918	·8	7666·6350	310·390
·1	7253·3339	301·9078	·5	7466·2087	306·3060	·9	7682·1623	310·704
·2	7268·4372	302·2219	·6	7481·5319	306·6202	99·	7697·7054	311·018
·3	7283·5561	302·5361	·7	7496·8708	306·9343	·1	7713·2642	311·332
·4	7298·6908	302·8502	·8	7512·2253	307·2485	·2	7728·8337	311·646
·5	7313·8411	303·1644	·9	7527·5956	307·5626	·3	7744·4288	311·960
·6	7329·0072	303·4786	98·	7542·9816	307·8768	·4	7760·0347	312·275
·7	7344·1890	303·7927	·1	7558·3833	308·1910	·5	7775·6563	312·589
·8	7359·3865	304·1069	·2	7573·8007	308·5051	·6	7791·2937	312·903
·9	7374·5997	304·4210	·3	7589·2338	308·8193	·7	7806·9467	313·217
97·	7389·8286	304·7352	·4	7604·6826	309·1334	·8	7822·6154	313·531
·1	7405·0732	305·0494	·5	7620·1471	309·4476	·9	7838·2999	313·845
·2	7420·3335	305·3635	·6	7635·6274	309·7618	100·	7854·0000	314·16
·3	7435·6096	305·6777	·7	7651·1233	310·0759			

CONTENTS OF SPHERES.

Dia.	Contents.	Dia.	Contents.	Dia.	Contents.	Dia.	Contents.	Dia.	Contents.
·1	·000523	2·1	4·849	4·1	36·087	6·1	118·847	8·1	278·262
·2	·004189	·2	5·575	·2	38·792	·2	124·788	·2	288·696
·3	·014137	·3	6·371	·3	41·630	·3	130·924	·3	299·387
·4	·033510	·4	7·238	·4	44·602	·4	137·258	·4	310·339
·5	·065450	·5	8·181	·5	47·713	·5	143·793	·5	321·555
·6	·113097	·6	9·203	·6	50·965	·6	150·533	·6	333·038
·7	·179594	·7	10·306	·7	54·362	·7	157·479	·7	344·791
·8	·268082	·8	11·494	·8	57·906	·8	164·636	·8	356·818
·9	·381703	·9	12·770	·9	61·601	·9	172·007	·9	369·121
1·0	·523599	3·0	14·137	5·0	65·450	7·0	179·594	9·0	381·703
·1	·696910	·1	15·598	·1	69·456	·1	187·402	·1	394·569
·2	·904779	·2	17·157	·2	73·622	·2	195·432	·2	407·720
·3	1·150349	·3	18·816	·3	77·952	·3	203·689	·3	421·160
·4	1·436758	·4	20·579	·4	82·448	·4	212·175	·4	434·893
·5	1·767250	·5	22·449	·5	87·114	·5	220·893	·5	448·921
·6	2·144665	·6	24·429	·6	91·952	·6	229·847	·6	463·247
·7	2·572446	·7	26·552	·7	96·967	·7	239·040	·7	477·875
·8	3·053635	·8	28·731	·8	102·160	·8	248·475	·8	492·807
·9	3·591372	·9	31·059	·9	107·536	·9	258·155	·9	508·847
2·0	4·188800	4·0	33·510	6·0	113·097	8·0	268·083	10·0	523·599

Digitized by Google

THE OHM.

Stated in algebraic formula, the equation for the Ohm would be c equals e divided by r. In this equation, e represents the electro-motive force in volts, r is the resistance in Ohms and c is the current in amperes.

The above demonstrates the law that the strength of the current in a wire or other conductor is directly proportional to the difference of potential between its ends and inversely proportionate to its resistance.

At the electrical congress held in Chicago at the World's Fair in 1893, a commission went over the ground and established the following units, which have been adopted the world over. The Ohm is represented by the resistance of a a column of mercury one square millimetre section at the temperature of 32° Fahrenheit, having a length of 106.3 Centimetres.

The current produced by a volt through an Ohm's resistance is called an ampere. A coulomb is the quantity of electricity defined by the condition that an ampere flowing for one second gives a coulomb. A farad is defined by the condition that a charge of one coulomb gives a potential of one volt at its terminals. A volt is the E. M. F. that will sustain a current of one ampere in a conductor whose resistance is an Ohm.

Digitized by Google

DECIMAL EQUIVALENTS, ALSO SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS, OF FRACTIONS.

Fraction.	Equivalent.	Square.	Cube.	Square root.	Cube root.
$\frac{1}{64}$	·015625	·00024399	·000003811	·125	·25
$\frac{1}{32}$	·03125	·00097656	·000030518	·17698	·31494
$\frac{3}{64}$	·046875	·0021963	·00010293	·21648	·36054
$\frac{1}{16}$	·0625	·0039062	·00024414	·25	·39686
$\frac{5}{64}$	·078125	·0061035	·00047684	·27951	·42749
$\frac{3}{32}$	·09375	·0087891	·00082397	·30618	·45428
$\frac{7}{64}$	·109375	·0119662	·0013083	·32430	·47823
$\frac{1}{8}$	·125	·015625	·0019531	·35355	·5
$\frac{9}{64}$	·140625	·019683	·0027615	·37456	·51962
$\frac{5}{32}$	·15625	·024414	·0038147	·39529	·53861
$\frac{11}{64}$	·171875	·029532	·0050751	·41455	·55595
$\frac{3}{16}$	·1875	·035156	·0065918	·42316	·57236
$\frac{13}{64}$	·203125	·041270	·0083840	·45077	·58786
$\frac{7}{32}$	·21875	·047851	·010467	·46771	·60254
$\frac{15}{64}$	·234375	·054929	·012874	·48412	·61655
$\frac{1}{4}$	·25	·062500	·015625	·5	·62996
$\frac{17}{64}$	·265625	·070554	·018741	·51538	·64282
$\frac{9}{32}$	·28125	·079102	·022247	·53033	·65519
$\frac{19}{64}$	·296875	·088132	·026164	·54486	·66710
$\frac{5}{16}$	·3125	·097656	·030518	·55902	·67860
$\frac{21}{64}$	·328125	·107666	·035326	·57282	·68973
$\frac{11}{32}$	·34375	·118162	·040619	·58630	·70051
$\frac{23}{64}$	·359375	·129151	·046411	·59948	·71096
$\frac{3}{8}$	·375	·140625	·052734	·61237	·72113
$\frac{25}{64}$	·390625	·15258	·059602	·62499	·73100
$\frac{13}{32}$	·40625	·16504	·067047	·63738	·74062
$\frac{27}{64}$	·421875	·17797	·075508	·64951	·75
$\frac{7}{16}$	·4375	·19140	·083740	·66144	·75915
$\frac{29}{64}$	·453125	·20531	·093033	·67314	·76808
$\frac{15}{32}$	·46875	·21973	·103000	·68465	·77681
$\frac{31}{64}$	·484375	·23461	·113642	·69596	·78534
$\frac{1}{2}$	·5	·25	·125	·70711	·79370

Digitized by Google

DECIMAL EQUIVALENTS, ALSO SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS, OF FRACTIONS.

Fraction.	Equivalent.	Square.	Cube.	Square root.	Cube root.
$\frac{33}{64}$	·515625	·26585	·13708	·71806	·80188
$\frac{17}{32}$	·53125	·28223	·14993	·72895	·80996
$\frac{35}{64}$	·546875	·29907	·16355	·73951	·81776
$\frac{9}{16}$	·5625	·31641	·17798	·75	·82548
$\frac{37}{64}$	·578125	·33422	·19322	·76034	·83305
$\frac{19}{32}$	·59375	·35254	·20932	·77055	·84049
$\frac{39}{64}$	·609375	·37133	·22628	·78062	·84780
$\frac{5}{8}$	·625	·39063	·24414	·79057	·85499
$\frac{41}{64}$	·640625	·41039	·26290	·80039	·86205
$\frac{21}{32}$	·65625	·43066	·28262	·81009	·86901
$\frac{43}{64}$	·671875	·45141	·30329	·81968	·87585
$\frac{11}{16}$	·6875	·47266	·32495	·82917	·88258
$\frac{45}{64}$	·703125	·49438	·34761	·83852	·88922
$\frac{23}{32}$	·71875	·51660	·37131	·84779	·89576
$\frac{47}{64}$	·734375	·53930	·39604	·84695	·90220
$\frac{3}{4}$	·75	·56250	·42188	·86602	·90856
$\frac{49}{64}$	·765625	·58617	·44879	·875	·91482
$\frac{25}{32}$	·78125	·61035	·47684	·88388	·92101
$\frac{51}{64}$	·796875	·63500	·50602	·89267	·92711
$\frac{13}{16}$	·8125	·66013	·53636	·90139	·93313
$\frac{53}{64}$	·828125	·68578	·56791	·91001	·93907
$\frac{27}{32}$	·84375	·71191	·60068	·91856	·94494
$\frac{55}{64}$	·859375	·73852	·63466	·92702	·95074
$\frac{7}{8}$	·875	·76563	·66992	·93541	·95646
$\frac{57}{64}$	·890625	·79142	·70644	·94320	·96176
$\frac{29}{32}$	·90625	·82129	·74429	·95197	·96772
$\frac{59}{64}$	·921875	·84984	·78344	·96014	·97325
$\frac{15}{16}$	·9375	·87891	·82397	·96825	·97872
$\frac{61}{64}$	·953125	·90845	·86586	·97632	·98415
$\frac{31}{32}$	·96875	·93848	·90915	·98425	·98947
$\frac{63}{64}$	·984375	·96898	·95384	·99215	·99476
1	1·	1·0	1·0	1·0	1·0

MIM KAPH MIM LIBRARY
CHEM. BLDG. U. C
Digitized by Google

Squares, Cubes, and Square and Cube Roots, of all Numbers from 1 to 500, and 4th and 5th Powers of Numbers 1 to 150.

No.	Square.	Cube.	4th Power.	5th Power.	Square Root.	Cube Root.
1	1	1	1	1	1·	1·
2	4	8	16	32	1·4142 136	1·2599 210
3	9	27	81	243	1·7320 508	1·4422 496
4	16	64	256	1024	2·	1·5874 011
5	25	125	625	3125	2·2360 680	1·7099 759
6	36	216	1296	7776	2·4494 897	1·8171 206
7	49	343	2401	16807	2·6457 513	1·9129 312
8	64	512	4096	32768	2·8284 271	2·
9	81	729	6561	59049	3·	2·0800 837
10	1 00	1 000	10000	100000	3·1622 777	2·1544 347
11	1 21	1 331	14641	161051	3·3166 248	2·2239 801
12	1 44	1 728	20736	248832	3·4641 016	2·2894 286
13	1 69	2 197	28561	371293	3·6055 513	2·3513 347
14	1 96	2 744	38416	537824	3·7416 574	2·4101 422
15	2 25	3 375	50625	759375	3·8729 833	2·4662 121
16	2 56	4 096	65536	1048576	4·	2·5198 421
17	2 89	4 913	83521	1419857	4·1231 056	2·5712 816
18	3 24	5 832	104976	1889568	4·2426 407	2·6207 414
19	3 61	6 859	130321	2476099	4·3588 989	2·6684 016
20	4 00	8 000	160000	3200000	4.4721 360	2·7144 177
21	4 41	9 261	194481	4084101	4·5825 757	2·7589 243
22	4 84	10 648	234256	5153632	4·6904 158	2·8020 393
23	5 29	12 167	279841	6436343	4·7958 315	2·8438 670
24	5 76	13 824	331776	7962624	4·8989 795	2·8844 991
25	6 25	15 625	390625	9765625	5·	2·9240 177
26	6 76	17 576	456976	11881376	5·0990 195	2·9624 960
27	7 29	19 683	531441	14348907	5·1961 524	3.
28	7 84	21 952	614656	17210368	5·2915 026	3·0365 889
29	8 41	24 389	707281	20511149	5·3851 648	3·0723 168
30	9 00	27 000	810000	24300000	5·4772 256	3·1072 325

Digitized by Google

SQUARES, CUBES, AND SQUARE AND CUBE ROOTS, OF ALL NUMBERS FROM 1 TO 500, AND 4TH AND 5TH POWERS OF NUMBERS 1 TO 150.

No.	Square.	Cube.	4th Power.	5th Power.	Square Root.	Cube Root.
31	9 61	29 791	923521	28629151	5·5677 644	3·1413 806
32	10 24	32 768	1048576	33554432	5·6568 542	3·1748 021
33	10 89	35 937	1185921	39135393	5·7445 626	3·2075 343
34	11 56	39 304	1336336	45435424	5·8309 519	3·2396 118
35	12 25	42 875	1500625	52521875	5·9160 798	3·2710 663
36	12 96	46 656	1679616	60466176	6·	3·3019 272
37	13 69	50 653	1874161	69343957	6·0827 625	3·3322 218
38	14 44	54 872	2085136	79235168	6·1644 140	3·3619 754
39	15 21	59 319	2313441	90224199	6·2449 998	3·3912 114
40	16 00	64 000	2560000	102400000	6·3245 553	3·4199 519
41	16 81	63 921	2825761	115856201	6·4031 242	3·4482 172
42	17 64	74 088	3111696	130391232	6·4807 407	3·4760 266
43	18 49	79 507	3418801	147008443	6·5574 385	3·5033 981
44	19 36	85 184	3748096	164916224	6·6332 496	3·5303 483
45	20 25	91 125	4100625	184528125	6·7082 039	3·5568 933
46	21 16	97 336	4477456	205962976	6·7823 300	3·5830 479
47	22 09	103 823	4879681	229345007	6·8556 546	3·6088 261
48	23 04	110 592	5308416	254803968	6·9282 032	3·6342 411
49	24 01	117 649	5764801	282475249	7·	3·6593 057
50	25 00	125 000	6250000	312500000	7·0710 678	3·6840 314
51	26 01	132 651	6765201	345025251	7·1414 284	3·7084 298
52	27 04	140 608	7311616	380204032	7·2111 026	3·7325 111
53	28 09	148 877	7890481	418195493	7·2801 099	3·7562 858
54	29 16	157 464	8503056	459165024	7·3484 692	3·7797 631
55	30 25	166 375	9150625	503284375	7·4161 985	3·8029 525
56	31 36	175 616	9834496	550731776	7·4833 148	3·8258 624
57	32 49	185 193	10556001	601692057	7·5498 344	3·8485 011
58	33 64	195 112	11316496	656356768	7·6157 731	3·8708 766
59	34 81	205 379	12117361	714924299	7·6811 457	3·8929 965
60	36 00	216 000	12960000	777600000	7·7459 667	3·9148 676
61	37 21	226 981	13845841	844596301	7·8102 497	3·9364 972
62	38 44	238 328	14776336	916132832	7·8740 079	3·9578 915
63	39 69	250 047	15752961	992436543	7·9372 539	3·9790 571
64	40 96	262 144	16777216	1073741824	8·	4·
65	42 25	274 625	17850625	1160290625	8·0622 577	4·0207 256
66	43 56	287 496	18974736	1252332576	8·1240 384	4·0412 401
67	44 89	300 763	20151121	1350125107	8·1853 528	4·0615 480
68	46 24	314 432	21381376	1453933568	8·2462 113	4·0816 551
69	47 61	328 509	22667121	1564031349	8·3066 239	4·1015 661
70	49 00	343 000	24010000	1680700000	8·3666 003	4·1212 853

Digitized by Google

SQUARES, CUBES, AND SQUARE AND CUBE ROOTS, OF ALL NUMBERS FROM 1 TO 500, AND 4TH AND 5TH POWERS OF NUMBERS 1 TO 150.

No.	Square.	Cube.	4th Power.	5th Power.	Square Root.	Cube Root.
71	50 41	357 911	25411681	1804229351	8·4261 498	4·1408 178
72	51 84	373 248	26873856	1934917632	8·4852 814	4·1601 676
73	53 29	389 017	28398241	2073071593	8·5440 037	4·1793 390
74	54 76	405 224	29986576	2219006624	8·6023 253	4·1983 364
75	56 25	421 875	31640625	2373046875	8·6602 540	4·2171 633
76	57 76	438 976	33362176	2535525376	8·7177 979	4·2358 236
77	59 29	456 533	35153041	2706784157	8·7749 644	4·2543 210
78	60 84	474 552	37015056	2887174368	8·8317 609	4·2726 586
79	62 41	493 039	38950081	3077056399	8·8881 944	4·2908 404
80	64 00	512 000	40960000	3276800000	8·9442 719	4·3088 695
81	65 61	531 441	43046721	3486784401	9·	4·3267 487
82	67 24	551 368	45212176	3707398432	9·0553 851	4·3444 815
83	68 89	571 787	47458321	3939040643	9·1104 336	4·3620 707
84	70 56	592 704	49787136	4182119424	9·1651 514	4·3795 191
85	72 25	614 125	52200625	4437053125	9·2195 445	4·3968 296
86	73 96	636 056	54708016	4704270176	9·2736 185	4·4140 049
87	75 69	658 503	57289761	4984209207	9·3273 791	4·4310 476
88	77 44	681 472	59969536	5277319168	9·3808 315	4·4479 602
89	79 21	704 969	62742241	5584059449	9·4339 811	4·4647 451
90	81 00	729 000	65610000	5904900000	9·4868 330	4·4814 047
91	82 81	753 571	68574961	6240321451	9·5393 920	4·4979 414
92	84 64	778 688	71639296	6590815232	9·5916 630	4·5143 574
93	86 49	804 357	74805201	6956883693	9·6436 508	4·5306 549
94	88 36	830 584	78074896	7339040224	9·6953 597	4·5468 359
95	90 25	857 375	81450625	7737809375	9·7467 943	4·5629 026
96	92 16	884 736	84934656	8153726976	9·7979 590	4·5788 570
97	94 09	912 673	88529281	8587340257	9·8488 578	4·5947 009
98	96 04	941 192	92236816	9039207968	9·8994 949	4·6104 363
99	98 01	970 299	96059601	9509900499	9·9498 744	4·6260 650
100	1 00 00	1 000 000	100000000	10000000000	10·	4·6415 888
101	1 02 01	1 030 301	104060401	10510100501	10·0498 756	4·6570 095
102	1 04 04	1 061 208	108243216	11040808032	10·0995 049	4·6723 287
103	1 06 09	1 092 727	112550881	11592740743	10·1488 916	4·6875 482
104	1 08 16	1 124 864	116985856	12166529024	10·1980 390	4·7026 694
105	1 10 25	1 157 625	121550625	12762815625	10·2469 508	4·7176 940
106	1 12 36	1 191 016	126247696	13382255776	10·2956 301	4·7326 235
107	1 14 49	1 225 043	131079601	14025517307	10·3440 804	4·7474 594
108	1 16 64	1 259 712	136048896	14693280768	10·3923 048	4·7622 032
109	1 18 81	1 295 029	141158161	15386239549	10·4403 065	4·7768 562
110	1 21 00	1 331 000	146410000	16105100000	10·4880 885	4·7914 199

Digitized by Google

SQUARES, CUBES, AND SQUARE AND CUBE ROOTS, OF ALL NUMBERS FROM 1 TO 500, AND 4TH AND 5TH POWERS OF NUMBERS 1 TO 150.

No.	Square.	Cube.	4th Power.	5th Power.	Square Root.	Cube Root.
111	1 23 21	1 367 631	151807041	16850581551	10·5356 538	4·8058 955
112	1 25 44	1 404 928	157351936	17623416832	10·5830 052	4·8202 845
113	1 27 69	1 442 897	163047361	18424351793	10·6301 458	4·8345 881
114	1 29 96	1 481 544	168896016	19254145824	10·6770 783	4·8488 076
115	1 32 25	1 520 875	174900625	20113581875	10·7238 053	4·8629 442
116	1 34 56	1 560 896	181063936	21003416576	10·7703 296	4·8769 990
117	1 36 89	1 601 613	187388721	21924480357	10·8166 538	4·8909 732
118	1 39 24	1 643 032	193877776	22877577568	10·8627 805	4·9048 681
119	1 41 61	1 685 159	200533921	23863536599	10·9087 121	4·9186 847
120	1 44 00	1 728 000	207360000	24883200000	10·9544 512	4·9324 242
121	1 46 41	1 771 561	214358881	25937424601	11·	4·9460 874
122	1 48 84	1 815 848	221533456	27027081632	11·0453 610	4·9596 757
123	1 51 29	1 860 867	228886641	28153056843	11·0905 365	4·9731 898
124	1 53 76	1 906 624	236421376	29316250624	11·1355 287	4·9866 310
125	1 56 25	1 953 125	244140625	30517578125	11·1803 399	5·
126	1 58 76	2 000 376	252047376	31757969376	11·2249 722	5·0132 979
127	1 61 29	2 048 383	260144641	33038369407	11·2694 277	5·0265 257
128	1 63 84	2 097 152	268435456	34359738368	11·3137 085	5·0396 842
129	1 66 41	2 146 689	276922881	35723051649	11·3578 167	5·0527 743
130	1 69 00	2 197 000	285610000	37129300000	11·4017 543	5·0657 970
131	1 71 61	2 248 091	294499921	38579489651	11·4455 231	5·0787 531
132	1 74 24	2 299 968	303595776	40074642432	11·4891 253	5·0916 434
133	1 76 89	2 352 637	312900721	41615795893	11·5325 626	5·1044 687
134	1 79 56	2 406 104	322417936	43204003424	11·5758 369	5·1172 299
135	1 82 25	2 460 375	332150625	44840334375	11·6189 500	5·1299 278
136	1 84 96	2 515 456	342102016	46525874176	11·6619 038	5·1425 632
137	1 87 69	2 571 353	352275361	48261724457	11·7046 999	5·1551 367
138	1 90 44	2 628 072	362673936	50049003168	11·7473 401	5·1676 493
139	1 93 21	2 685 619	373301641	51888844699	11·7898 261	5·1801 015
140	1 96 00	2 744 000	384160000	53782400000	11·8321 596	5·1924 941
141	1 98 81	2 803 221	395254161	55730836701	11·8743 422	5·2048 279
142	2 01 64	2 863 288	406586896	57735339232	11·9163 753	5·2171 034
143	2 04 49	2 924 207	418161601	59797108943	11·9582 607	5·2293 215
144	2 07 36	2 985 984	429981696	61917364224	12·	5·2414 828
145	2 10 25	3 048 625	442050625	64097340625	12·0415 946	5·2535 879
146	2 13 16	3 112 136	454371856	66338290976	12·0830 460	5·2656 374
147	2 16 09	3 176 523	466948881	68641485507	12·1243 557	5·2776 321
148	2 19 04	3 241 792	479785216	71008211968	12·1655 251	5·2895 725
149	2 22 01	3 307 949	492884401	73439775749	12·2065 556	5·3014 592
150	2 25 00	3 375 000	506250000	75937500000	12·2474 487	5·3132 928

Digitized by Google

METRIC AND ENGLISH SYSTEMS OF MEASURE, AND THEIR RELATION TO ONE ANOTHER.

One of the advantages of the metric system consists in the fact that the weight of any quantity of material is found in tons, or in kilogrammes, or in grammes, simply by multiplying its volume in cubic meters or cubic decimeters, or in cubic centimeters by its specific gravity; thus the specific gravity of cast aluminum being 2.56, the weight of a cubic metre of cast aluminum is 2560 kilogrammes.

The following data regarding weights and measures, is quoted from "Gauges at a Glance," by Thomas Taylor:

MEASURE.

The mere mention of the fact that the English system of measures is based upon the length of Henry I.'s arm, is enough to condemn it in the eyes of many. He measured his arm, declared it to be the "ulna," or ancient ell. This was well maintained, and in 1742 the Royal Society carefully prepared a standard from the ells of Henry VII., and Elizabeth kept at the Exchequer, In 1758 an exact copy was made of this Royal Society's yard, examined by a Committee of the House of Commons, then marked and approved. The Act of George IV. declares this "straight brass rod," &c., to be our standard and unit; all other measures, whether lineal, superficial or solid, to be derived from it:

> "and that ⅓rd yard of the said standard yard shall be "a foot, and the 12th part of such foot shall be an "inch: and that the pole or perch in length shall con- "tain 5½ such yards, the furlong 220 such yards, and "the mile 1760 such yards."

And further for area:

> "The rood of land shall contain 1,210 square yards, "according to the said standard yard; and that the "acre of land shall contain 4,840 such square yards, "being 160 square perches, poles or rods."

Digitized by Google

If the standard yard gets lost or destroyed, its recovery is provided for by reference to the Pendulum at London.

The following tables give its relation to the Metric system:

		INCHES.	
1 Millimetre	=	0.039370	= (about $\frac{1}{25}$th inch.)
1 Centimetre	=	0.393704	
1 Decimetre	=	3.937043	= $3\frac{15}{16}$ inches.
1 Metre	=	39.370432	= 3 feet $3\frac{3}{8}$th inches, or 3.28 feet.
1 Decametre	=	393.704320	= 32 feet, $9\frac{11}{16}$th inch.
1 Hectometre	=	3937.043196	= 109 yards 1 foot 1 inch.
1 Kilometre	=	39370.431960	= 1093 yards 1 foot $10\frac{7}{16}$th inch, or .6214 miles.
1 Myriametre	=	393704.319600	= 6 miles 376 yards 0 feet $8\frac{5}{16}$th inch, or 6.214 miles.

WEIGHTS.

The great advantage of the Metric System lies not so much in its determination as in its application. The former gives it a more scientific or philosophical basis: the latter the great merit of usefulness. The metre is determined by a terrestrial meridian; our yard from Henry I.'s arm, checked by the oscillations of a pendulum at London. This gives the yard an arbitrary character as the oscillations vary in different parallels of latitude, and hence its inferiority from a scientific standpoint. But having got our basis or unit it would not much matter *how*, so long as we proceeded to divide or multiply it for use in a rational way. When George IV., was king, the British act establishing uniform measures throughout the kingdom took effect on January 1, 1826 (5 George IV., c. 74.) Why the only rational system, the decimal system, was not then inaugurated, and tons, cwts, qrs., drams, &c., swept away, passes the comprehension of ordinary folk. It seems incredible, but it is true, that "Heaped" measure was actually preserved. This gross absurdity was left for the wisdom of William IV., to abolish at the close of 1835.

Digitized by Google

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

SCHEME OF THE WEIGHTS AND MEASURES OF THE METRIC SYSTEM.

Ratios.	Length.	Surfaces.	Volumes.	Weights.
1,000,000	....	....	....	Millier or Tonneau..........
100,000	....	....	....	Quintal..........................
10,000	Myriameter..........	....	....	Myriagram....................
1,000	Kilometer..............	....	Kiloliter..................	Kilogram or Kilo...........
100	Hectometer...........	Hectare................	Hectoliter................	Hectogram....................
10	Dekameter.............	....	Dekaliter.................	Dekagram.....................
1	Meter.....................	Are........................	Liter.......................	Gram..............................
.1	Decimeter..............	....	Deciliter..................	Decigram.......................
.01	Centimeter............	Centare..................	Centiliter................	Centigram.....................
.001	Millimeter.............	....	Milliliter.................	Milligram.......................

It will be seen from this table that 10 Millimeters equal 1 Centimeter, 10 Centimeters equal 1 Decimeter, and so on.

MEASURES OF LENGTHS.

Metric Denominations and Values.		Equivalents in Denominations in use.	Metric Denominations and Values.		Equivalents in English Denominations in use.
Myriameter...	10,000 Meters.	6.2138 miles..........................	Meter..........	1. Meter....	39.37 inches....................
Kilometer.....	1,000 Meters.	0.62138 miles or 3280 ft. 10 ins	Decimeter....	.1 Meter....	3.937 inches....................
Hectometer...	100 Meters.	328 feet 1 inch.........................	Centimeter...	.01 Meter....	.3937 inch........................
Dekameter....	10 Meters.	393.7 inches..........................	Millimeter...	.001 Meter....	.0394 inch........................

MEASURES OF SURFACE.

Metric Denominations and Values.		Equivalents in English Denominations in use.
Hectare..	10,000 Square Meters......................	2.471 Acres..................................
Are..	100 Square Meters.........................	119.6 Square Yards........................
Centare..	1 Square Meter..............................	1550 Square Inches........................

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.—Continued.

MEASURES OF CAPACITY.

Metric Denominations and Values			Equivalents in U. S. Denominations in use.	
Names.	No. of Liters.	Cubic Measure.	Dry Measure.	Liquid or Wine Measure.
Kiloliter or Stere	1,000	1 Cubic Meter	1.308 Cubic Yards	264.17 Gallons
Hectoliter	100	.1 Cubic Meter	2.8377 Bushels, 11,351 Pecks	26.417 Gallons
Dekaliter	10	10. Cubic Decimeter	9.081 Quarts	2.6417 Gallons
Liter	1	1. Cubic Decimeter	.9081 Quart	1.0567 Quarts
Deciliter	.1	.1 Cubic Decimeter	6.1023 Cubic Inches	.845 Gill
Centiliter	.01	10. Cubic Centimeter	.6102 Cubic Inch	.338 Fluid Ounce
Milliliter	.001	1. Cubic Centimeter	.061 Cubic Inch	.27 Fluid Drachm

WEIGHTS.

Metric Denominations and Values.			Equivalents in English Denominations in use.
Names.	Number of Grams.	Weight of what quantity of Water at Maximum Density.	Avoirdupois Weight.
Millier or Tonneau	1,000,000	1 Cubic Meter	2204.6 Pounds
Quintal	100,000	1 Hectoliter	220.46 Pounds
Myriagram	10,000	10 Liters	22.046 Pounds
Kilogram or Kilo	1,000	1 Liter	2.2046 Pounds
Hectogram	100	1 Deciliter	3.5274 Ounces
Dekagram	10	10 Cubic Centimeters	.3527 Ounce
Gram	1	1 Cubic Centimeter	15.432 Grains
Decigram	.1	.1 Cubic Centimeter	1.5432 Grains
Centigram	.01	10 Cubic Millimeters	.1543 Grain
Milligram	.001	1 Cubic Millimeter	.0154 Grain

Digitized by Google

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.—Continued.

COMMON MEASURES AND WEIGHTS WITH THEIR METRIC EQUIVALENTS.

Com. Measures.	Equivalents.	Com. Measures.	Equivalents.	Com. Measures.	Equivalents.
An Inch	2.54 Centimeters	An Acre	.4047 Hectare	A Dry Quart	1.101 Liters
A Foot	.3048 Meter.	A Sq. Mile	258.99 Hectares	A Peck, U. S.	8.809 Liters
A Yard	.9144 Meter.	A Sq. Inch	6.451 Sq. Centim's	A Bushel, U. S.	35.24 Liters
A Rod	5.029 Meters	A Cubic Inch	16.39 Cub. Centim's	An Oz.-Av.	28.35 Grams
A Mile	1.6093 Kilometers	A Cubic Foot	.02832 Cubic Meter	A Lb.-Av.	.4536 Kilogram
A Square Inch.	6.4513 Sq. Centimeters	A Cubic Yard	.7645 Cubic Meter	A Ton	.9071 Tonneau
A Square Foot.	.0929 Square Meter	A Cord	3.624 Steres	A Grain, Troy.	.0648 Gram
A Square Yard.	.836 Square Meter	A Liquid Qt.	.9464 Liter	An Oz., Troy	31.104 Grams
A Square Rod	25.29 Square Meters	A Gallon	3.785 Liters	A Lb., Troy	.3732 Kilogram

In the French Metric System, the Meter is the base of all the weights and measures which it employs.

The Meter was intended to be, and is very nearly one ten-millionth part of the distance measured on a meridian of the earth from the equator to the pole, and equals about 39.37 inches or nearly 3 feet, 3⅜ inches.

The Meter is the primary unit of length.

Upon the Meter are based the following primary units; The Square Meter, the Are, the Cubic Meter or Stere, the Liter and the Gram.

The Square Meter is the unit of measure for small surfaces: as the surface of a floor, table, etc.

The Are is the unit of land measure; this is a square whose side is ten meters in length and which contains one hundred square meters.

The Cubic Meter or Stere, is the unit of volume; this is a cube whose edge is one meter in length.

The Liter is the unit of capacity; this is the capacity of a cube whose edge is one-tenth of a meter in length.

The Gram is the unit of weight; this is the weight of distilled water contained in a cube whose edge is the one-hundredth part of a meter.

From these primary units, the higher and lower orders of units are derived decimally.

The prefixes denoting multiples are derived from the Greek language and are: Deka, ten; Hecto, hundred; Kilo, thousand; Myria, ten-thousand. Those denoting sub-multiples are from the Latin and are: Deci, tenth; Centi, hundredth, and Mili, thousandth.

The money system of France is connected with that of Metric weights by an authorized coin of silver, (the standard being 9 parts silver and 1 of alloy) representing the unit called the Franc and weighing 5 grams. The other coins are multiples and sub-multiples of the franc. The ratio of value of gold and silver is fixed by law at 15½ to 1. The 20-franc gold piece therefore, weighs 100 grams, divided by 15½=6.4516 grams of standard gold.

Digitized by Google

INCHES AND FRACTIONS OF AN INCH AND THEIR EQUIVALENTS IN MILLIMETRES.

Fractions of an inch.	Milli-metres.	Inches.	Milli-metres.	Inches.	Milli-metres.	Inches.	Milli-metres.
$\frac{1}{32}$	0·7937	1	25·3998	35	888·9920	69	1752·5842
$\frac{1}{16}$	1·5875	2	50·7995	36	914·3918	70	1777·9840
$\frac{3}{32}$	2·3812	3	76·1993	37	939·7916	71	1803·3838
$\frac{1}{8}$	3·1749	4	101·5991	38	965·1913	72	1828·7836
$\frac{5}{32}$	3·9688	5	126·9989	39	990·5911	73	1854·1833
$\frac{3}{16}$	4·7624	6	152·3986	40	1015·9908	74	1879·5831
$\frac{7}{32}$	5·5562	7	177·7984	41	1041·3906	75	1904·9828
$\frac{1}{4}$	6·3499	8	203·1982	42	1066·7904	76	1930·3826
$\frac{9}{32}$	7·1437	9	228·5979	43	1092·1902	77	1955·7824
$\frac{5}{16}$	7·9374	10	253·9977	44	1117·5899	78	1981·1822
$\frac{11}{32}$	8·7312	11	279·3975	45	1142·9897	79	2006·5819
$\frac{3}{8}$	9·5249	12	304·7973	46	1168·3895	80	2031·9817
$\frac{13}{32}$	10·3186	13	330·1970	47	1193·7883	81	2057·3815
$\frac{7}{16}$	11·1124	14	355·5968	48	1219·1890	82	2082·7813
$\frac{15}{32}$	11·9061	15	380·9966	49	1244·5888	83	2108·1810
$\frac{1}{2}$	12·6998	16	406·3963	50	1269·9886	84	2133·5808
$\frac{17}{32}$	13·4936	17	431·7961	51	1295·3883	85	2158·9806
$\frac{9}{16}$	14·2874	18	457·1959	52	1320·7881	86	2184·3803
$\frac{19}{32}$	15·0811	19	482·5957	53	1346·1879	87	2209·7791
$\frac{5}{8}$	15·8748	20	507·9954	54	1371·5877	88	2235·1798
$\frac{21}{32}$	16·6686	21	533·3952	55	1396·9874	89	2260·5796
$\frac{11}{16}$	17·4623	22	558·7949	56	1422·3872	90	2285·9794
$\frac{23}{32}$	18·2561	23	584·1948	57	1447·7869	91	2311·3792
$\frac{3}{4}$	19·0498	24	609·5945	58	1473·1868	92	2336·7789
$\frac{25}{32}$	19·8436	25	634·9943	59	1498·5865	93	2362·1787
$\frac{13}{16}$	20·6373	26	660·3941	60	1523·9863	94	2387·5765
$\frac{27}{32}$	21·4310	27	685·7938	61	1549·3861	95	2412·9763
$\frac{7}{8}$	22·2248	28	711·1936	62	1574·7858	96	2438·3781
$\frac{29}{32}$	23·0185	29	736·5934	63	1599·1856	97	2463·7778
$\frac{15}{16}$	23·8123	30	761·9932	64	1625·5854	98	2489·1776
$\frac{31}{32}$	24·6060	31	787·3929	65	1650·9842	99	2514·5774
		32	812·7927	66	1676·3859	100	2539·9772
		33	838·1925	67	1701·7857	101	2565·3769
		34	863·5922	68	1727·1845	102	2590·7767

The above Table may be used for decimals of inches by altering the decimal point both Inches and Millimetres in the same number of places.

Digitized by Google

MILLIMETRES REDUCED TO INCHES AND DECIMALS OF AN INCH.

Millimetres	Inches.	Millimetres	Inches.	Millimetres	Inches.	Millimetres	Inches.	Millimetres	Inches.
1	·03937	41	1·6142	81	3·1890	121	4·7638	161	6·3386
2	·07874	42	1·6536	82	3·2284	122	4·8032	162	6·3780
3	·11811	43	1·6929	83	3·2677	123	4·8426	163	6·4174
4	·15748	44	1·7323	84	3·3071	124	4·8819	164	6·4568
5	·19685	45	1·7717	85	3·3465	125	4·9213	165	6·4961
6	·23622	46	1·8110	86	3·3859	126	4·9607	166	6·5355
7	·27559	47	1·8504	87	3·4252	127	5·0000	167	6·5749
8	·31496	48	1·8898	88	3·4646	128	5·0394	168	6·6142
9	·35433	49	1·9291	89	3·5040	129	5·0788	169	6·6536
10	·3937	50	1·9685	90	3·5433	130	5·1182	170	6·6930
11	·4331	51	2·0079	91	3·5827	131	5·1575	171	6·7323
12	·4724	52	2·0473	92	3·6221	132	5·1969	172	6·7717
13	·5118	53	2·0866	93	3·6614	133	5·2363	173	6·8111
14	·5512	54	2·1260	94	3·7008	134	5·2756	174	6·8505
15	·5906	55	2·1654	95	3·7402	135	5·3150	175	6·8898
16	·6299	56	2·2047	96	3·7796	136	5·3544	176	6·9292
17	·6693	57	2·2441	97	3·8189	137	5·3937	177	6·9686
18	·7087	58	2·2835	98	3·8583	138	5·4331	178	7·0078
19	·7480	59	2·3229	99	3·8977	139	5·4725	179	7·0472
20	·7874	60	2·3622	100	3·9370	140	5·5119	180	7·0867
21	·8268	61	2·4016	101	3·9764	141	5·5512	181	7·1260
22	·8661	62	2·4410	102	4·0158	142	5·5906	182	7·1654
23	·9055	63	2·4803	103	4·0552	143	5·6300	183	7·2048
24	·9449	64	2·5197	104	4·0945	144	5·6693	184	7·2442
25	·9843	65	2·5591	105	4·1339	145	5·7087	185	7·2835
26	1·0236	66	2·5984	106	4·1733	146	5·7481	186	7·3229
27	1·0630	67	2·6378	107	4·2126	147	5·7875	187	7·3623
28	1·1024	68	2·6772	108	4·2520	148	5·8268	188	7·4016
29	1·1417	69	2·7166	109	4·2914	149	5·8662	189	7·4410
30	1·1811	70	2·7559	110	4·3308	150	5·9056	190	7·4804
31	1·2205	71	2·7953	111	4·3701	151	5·9449	191	7·5198
32	1·2599	72	2·8347	112	4·4095	152	5·9843	192	7·5591
33	1·2992	73	2·8740	113	4·4489	153	6·0237	193	7·5985
34	1·3386	74	2·9134	114	4·4882	154	6·0630	194	7·6379
35	1·3780	75	2·9528	115	4·5276	155	6·1024	195	7·6772
36	1·4173	76	2·9922	116	4·5670	156	6·1418	196	7·7166
37	1·4567	77	3·0315	117	4·6063	157	6·1812	197	7·7560
38	1·4961	78	3·0709	118	4·6457	158	6·2205	198	7·7953
39	1·5354	79	3·1103	119	4·6851	159	6·2599	199	7·8347
40	1·5748	80	3·1496	120	4·7245	160	6·2993	200	7·8741

Digitized by Google

MILLIMETRES REDUCED TO INCHES AND DECIMALS OF AN INCH.

Millimetres	Inches.	Millimetres	Inches.	Millimetres	Inches.	Millimetres	Inches.	Millimetres	Incnes.
201	7·9135	241	9·4883	281	11·0631	321	12·6379	361	14·2127
202	7·9528	242	9·5276	282	11·1024	322	12·6773	362	14·2520
203	7·9922	243	9·5670	283	11·1418	323	12·7166	363	14·2915
204	8·0316	244	9·6064	284	11·1812	324	12·7560	364	14·3308
205	8·0709	245	9·6458	285	11·2206	325	12·7954	365	14·3702
206	8·1103	246	9·6851	286	11·2599	326	12·8347	366	14·4096
207	8·1497	247	9·7245	287	11·2993	327	12·8741	367	14·4489
208	8·1890	248	9·7639	288	11·3387	328	12·9135	368	14·4883
209	8·2284	249	9·8032	289	11·3780	329	12·9528	369	14·5277
210	8·2678	250	9·8426	290	11·4174	330	12·9922	370	14·5671
211	8·3072	251	9·8820	291	11·4568	331	13·0316	371	14·6064
212	8·3465	252	9·9213	292	11·4962	332	13·0709	372	14·6458
213	8·3859	253	9·9607	293	11·5355	333	13·1103	373	14·6852
214	8·4253	254	10·0001	294	11·5749	334	13·1497	374	14·7245
215	8·4646	255	10·0395	295	11·6143	335	13·1891	375	14·7639
216	8·5040	256	10·0788	296	11·6536	336	13·2285	376	14·8033
217	8·5434	257	10·1182	297	11·6930	337	13·2678	377	14·8426
218	8·5828	258	10·1576	298	11·7324	338	13·3072	378	14·8820
219	8·6221	259	10·1969	299	11·7717	339	13·3466	379	14·9214
220	8·6615	260	10·2363	300	11·8111	340	13·3859	380	14·9608
221	8·7009	261	10·2757	301	11·8505	341	13·4253	381	15·0001
222	8·7402	262	10·3151	302	11·8899	342	13·4647	382	15·0395
223	8·7796	263	10·3544	303	11·9292	343	13·5040	383	15·0789
224	8·8190	264	10·3938	304	11·9686	344	13·5434	384	15·1182
225	8·8583	265	10·4332	305	12·0079	345	13·5828	385	15·1576
226	8·8977	266	10·4725	306	12·0473	346	13·6222	386	15·1969
227	8·9371	267	10·5119	307	12·0867	347	13·6615	387	15·2363
228	8·9765	268	10·5513	308	12·1261	348	13·7009	388	15·2757
229	9·0158	269	10·5906	309	12·1655	349	13·7403	389	15·3151
230	9·0552	270	10·6300	310	12·2049	350	13·7796	390	15·3545
231	9·0946	271	10·6694	311	12·2442	351	13·8190	391	15·3938
232	9·1339	272	10·7087	312	12·2836	352	13·8584	392	15·4332
233	9·1733	273	10·7481	313	12·3229	353	13·8978	393	15·4726
234	9·2127	274	10·7875	314	12·3623	354	13·9371	394	15·5119
235	9·2520	275	10·8269	315	12·4017	355	13·9765	395	15·5513
236	9·2914	276	10·8662	316	12·4410	356	14·0159	396	15·5907
237	9·3308	277	10·9056	317	12·4804	357	14·0552	397	15·6300
238	9·3702	278	10·9449	318	12·5198	358	14·0946	398	15·6694
239	9·4095	279	10·9843	319	12·5592	359	14·1339	399	15·7088
240	9·4489	280	11·0237	320	12·5985	360	14·1733	400	15·7482

Digitized by Google

MILLIMETRES REDUCED TO INCHES AND DECIMALS OF AN INCH.

Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.
401	15·7875	441	17·3624	481	18·9372	521	20·5120	561	22·0868
402	15·8269	442	17·4017	482	18·9765	522	20·5514	562	22·1262
403	15·8663	443	17·4411	483	19·0159	523	20·5908	563	22·1655
404	15·9056	444	17·4805	484	19·0553	524	20·6301	564	22·2049
405	15·9450	445	17·5198	485	19·0946	525	20·6695	565	22·2443
406	15·9844	446	17·5592	486	19·1340	526	20·7088	566	22·2837
407	16·0238	447	17·5986	487	19·1734	527	20·7482	567	22·3230
408	16·0631	448	17·6379	488	19·2128	528	20·7876	568	22·3624
409	16·1025	449	17·6773	489	19·2521	529	20·8269	569	22·4018
410	16·1419	450	17·7167	490	19·2915	530	20·8663	570	22·4411
411	16·1812	451	17·7561	491	19·3309	531	20·9058	571	22·4805
412	16·2206	452	17·7954	492	19·3702	532	20·9451	572	22·5199
413	16·2599	453	17·8349	493	19·4096	533	20·9844	573	22·5592
414	16·2993	454	17·8742	494	19·4490	534	21·0238	574	22·5986
415	16·3388	455	17·9135	495	19·4884	535	21·0632	575	22·6380
416	16·3781	456	17·9529	496	19·5277	536	21·1025	576	22·6774
417	16·4175	457	17·9923	497	19·5671	537	21·1419	577	22·7167
418	16·4569	458	18·0316	498	19·6065	538	21·1813	578	22·7561
419	16·4962	459	18·0710	499	19·6458	539	21·2207	579	22·7955
420	16·5356	460	18·1104	500	19·6852	540	21·2600	580	22·8349
421	16·5750	461	18·1498	501	19·7246	541	21·2995	581	22·8742
422	16·6143	462	18·1891	502	19·7640	542	21·3388	582	22·9136
423	16·6538	463	18·2286	503	19·8033	543	21·3781	583	22·9530
424	16·6931	464	18·2679	504	19·8427	544	21·4175	584	22·9923
425	16·7324	465	18·3072	505	19·8821	545	21·4569	585	23·0317
426	16·7718	466	18·3466	506	19·9214	546	21·4962	586	23·0711
427	16·8112	467	18·3860	507	19·9608	547	21·5356	587	23·1104
428	16·8505	468	18·4253	508	20·0002	548	21·5750	588	23·1499
429	16·8899	469	18·4647	509	20·0395	549	21·6144	589	23·1892
430	16·9293	470	18·5041	510	20·0789	550	21·6537	590	23·2285
431	16·9686	471	18·5435	511	20·1183	551	21·6931	591	23·2679
432	17·0080	472	18·5828	512	20·1577	552	21·7325	592	23·3073
433	17·0474	473	18·6222	513	20·1970	553	21·7718	593	23·3467
434	17·0868	474	18·6616	514	20·2364	554	21·8112	594	23·3860
435	17·1261	475	18·7009	515	20·2758	555	21·8506	595	23·4254
436	17·1655	476	18·7403	516	20·3151	556	21·8900	596	23·4648
437	17·2049	477	18·7797	517	20·3545	557	21·9293	597	23·5041
438	17·2442	478	18·8191	518	20·3939	558	21·9687	598	23·5435
439	17·2836	479	18·8584	519	20·4332	559	22·0081	599	23·5829
440	17·3230	480	18·8979	520	20·4726	560	22·0474	600	23·6222

Digitized by Google

MILLIMETRES REDUCED TO INCHES AND DECIMALS OF AN INCH.

Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.
601	23·6616	641	25·2364	681	26·8113	721	28·3861	761	29·9609
602	23·7010	642	25·2758	682	26·8506	722	28·4254	762	30·0003
603	23·7404	643	25·3152	683	26·8900	723	28·4648	768	30·0396
604	23·7797	644	25·3545	684	26·9294	724	28·5042	764	30·0790
605	23·8192	645	25·3939	685	26·9687	725	28·5436	765	30·1184
606	23·8585	646	25·4333	686	27·0081	726	28·5829	766	30·1577
607	23·8978	647	25·4727	687	27·0475	727	28·6223	767	30·1971
608	23·9372	648	25·5120	688	27·0868	728	28·6617	768	30·2365
609	23·9766	649	25·5514	689	27·1262	729	28·7010	769	30·2758
610	24·0160	650	25·5908	690	27·1656	730	28·7404	770	30·3152
611	24·0553	651	25·6301	691	27·2050	731	28·7798	771	30·3546
612	24·0947	652	25·6695	692	27·2443	732	28·8191	772	30·3940
613	24·1341	653	25·7089	693	27·2838	733	28·8585	773	30·4333
614	24·1734	654	25·7483	694	27·3231	734	28·8979	774	30·4727
615	24·2128	655	25·7876	695	27·3624	735	28·9373	775	30·5121
616	24·2522	656	25·8270	696	27·4018	736	28·9766	776	30·5514
617	24·2915	657	25·8664	697	27·4412	737	29·0160	777	30·5908
618	24·3309	658	25·9057	698	27·4805	738	29·0554	778	30·6302
619	24·3703	659	25·9451	699	27·5199	739	29·0947	779	30·6696
620	24·4097	660	25·9845	700	27·5593	740	29·1341	780	30·7089
621	24·4490	661	26·0238	701	27·5987	741	29·1735	781	30·7483
622	24·4885	662	26·0632	702	27·6380	742	29·2129	782	30·7877
623	24·5278	663	26·1026	703	27·6774	743	29·2522	783	30·8270
624	24·5671	664	26·1420	704	27·7168	744	29·2916	784	30·8664
625	24·6065	665	26·1813	705	27·7561	745	29·3310	785	30·9058
626	24·6459	666	26·2207	706	27·7955	746	29·3703	786	30·9451
627	24·6852	667	26·2601	707	27·8349	747	29·4097	787	30·9845
628	24·7246	668	26·2994	708	27·8743	748	29·4491	788	31·0239
629	24·7640	669	26·3388	709	27·9136	749	29·4884	789	31·0633
630	24·8034	670	26·3782	710	27·9530	750	29·5278	790	31·1026
631	24·8427	671	26·4175	711	27·9924	751	29·5672	791	31·1420
632	24·8821	672	26·4569	712	28·0317	752	29·6066	792	31·1814
633	24·9215	673	26·4963	713	28·0711	753	29·6459	793	31·2207
634	24·9608	674	26·5357	714	28·1105	754	29·6853	794	31·2601
635	25·0002	675	26·5750	715	28·1498	755	29·7247	795	31·2995
636	25·0396	676	26·6144	716	28·1892	756	29·7640	796	31·3389
637	25·0790	677	26·6538	717	28·2286	757	29·8034	797	31·3782
638	25·1183	678	26·6931	718	28·2680	758	29·8428	798	31·4176
639	25·1578	679	26·7325	719	28·3073	759	29·8821	799	31·4570
640	25·1971	680	26·7719	720	28·3467	760	29·9215	800	31·4963

Digitized by Google

MILLIMETRES REDUCED TO INCHES AND DECIMALS OF AN INCH.

Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.	Milli-metres	Inches.
801	31·5357	841	33·1105	881	34·6853	921	36·2602	961	37·8350
802	31·5751	842	33·1499	882	34·7247	922	36·2995	962	37·8743
803	31·6144	843	33·1893	883	34·7641	923	36·3389	963	37·9137
804	31·6538	844	33·2286	884	34·8035	924	36·3783	964	37·9531
805	31·6932	845	33·2681	885	34·8428	925	36·4176	965	37·9925
806	31·7326	846	33·3074	886	34·8822	926	36·4571	966	38·0318
807	31·7719	847	33·3467	887	34·9216	927	36·4964	967	38·0712
808	31·8113	848	33·3861	888	34·9609	928	36·5357	968	38·1106
809	31·8507	849	33·4255	889	35·0003	929	36·5751	969	38·1499
810	31·8900	850	33·4649	890	35·0397	930	36·6145	970	38·1893
811	31·9294	851	33·5042	891	35·0790	931	36·6539	971	38·2287
812	31·9688	852	33·5436	892	35·1184	932	36·6932	972	38·2680
813	32·0081	853	33·5830	893	35·1578	933	36·7326	973	38·3074
814	32·0475	854	33·6223	894	35·1972	934	36·7720	974	38·3468
815	32·0869	855	33·6617	895	35·2365	935	36·8113	975	38·3862
816	32·1263	856	33·7011	896	35·2759	936	36·8507	976	38·4255
817	32·1656	857	33·7404	897	35·3153	937	36·8901	977	38·4649
818	32·2050	858	33·7798	898	35·3546	938	36·9295	978	38·5043
819	32·2444	859	33.8192	899	35·3940	939	36·9688	979	38·5436
820	32·2837	860	33.8586	900	35·4334	940	37·0082	980	38·5830
821	32·3231	861	33·8979	901	35·4727	941	37·0476	981	38·6224
822	32·3625	862	33·9373	902	35·5121	942	37·0869	982	38·6618
823	32·4019	863	33·9767	903	35·5516	943	37·1263	983	38·7011
824	32·4412	864	34·0200	904	35·5909	944	37·1657	984	38·7405
825	32·4806	865	34·0554	905	35·6303	945	37·2050	985	38·7799
826	32·5200	866	34·0948	906	35·6697	946	37·2444	986	38·8192
827	32·5593	867	34·1342	907	35·7091	947	37·2838	987	38·8586
828	32·5987	868	34·1735	908	35·7484	948	37·3232	988	38·8980
829	32·6381	869	34·2129	909	35·7878	949	37·3625	989	38·9373
830	32·6774	870	34·2523	910	35·8271	950	37·4019	990	38·9767
831	32·7168	871	34·2916	911	35·8665	951	37·4413	991	39·0161
832	32·7562	872	34·3310	912	35·9058	952	37·4806	992	39·0555
833	32·7956	873	34·3704	913	35·9452	953	37·5200	993	39·0948
834	32·8349	874	34·4097	914	35·9846	954	37·5594	994	39·1342
835	32·8743	875	34·4491	915	36·0239	955	37·5988	995	39·1736
836	32·9137	876	34·4885	916	36·0633	956	37·6381	996	39·2129
837	32·9530	877	34·5279	917	36·1027	957	37·6775	997	39·2523
838	32·9924	878	34·5672	918	36·1420	958	37·7169	998	39·2917
839	33·0318	879	34·6066	919	36·1814	959	37·7562	999	39·3310
840	33·0712	880	34·6459	920	36·2208	960	37·7956	1000	39·3704

Digitized by Google

FEET AND THEIR EQUIVALENTS IN METRES.

Feet.	Metres.	Feet.	Metres.	Feet.	Metres.	Feet.	Metres.
1	·304	29	8·839	57	17·373	84	25·602
2	·609	30	9·143	58	17·678	85	25 907
3	·914	31	9·448	59	17·983	86	26·212
4	1·219	32	9·753	60	18·287	87	26·517
5	1·523	33	10·058	61	18·592	88	26·822
6	1·828	34	10·363	62	18·897	89	27·126
7	2·133	35	10·667	63	19·202	90	27·431
8	2·438	36	10·972	64	19·507	91	27·736
9	2·743	37	11·277	65	19·811	92	28·041
10	3·047	38	11·582	66	20·116	93	28·346
11	3·352	39	11·887	67	20·421	94	28·650
12	3·657	40	12·191	68	20·726	95	28·955
13	3·962	41	12·496	69	21·030	96	29·260
14	4·267	42	12·801	70	21·335	97	29·565
15	4·571	43	13·106	71	21·640	98	29·870
16	4·876	44	13·411	72	21·945	99	30·174
17	5·181	45	13·715	73	22·250	100	30·479
18	5·486	46	14·020	74	22·554	200	60·959
19	5·791	47	14·325	75	22·859	300	91·439
20	6·095	48	14·630	76	23·164	400	121·918
21	6·400	49	14·935	77	23·469	500	152·398
22	6·705	50	15·239	78	23·774	600	182·878
23	7·010	51	15·544	79	24·078	700	213·357
24	7·315	52	15·849	80	24·383	800	243·837
25	7·619	53	16·154	81	24·688	900	274·317
26	7·924	54	16·459	82	24·993	1000	304·796
27	8·229	55	16·763	83	25·298	5280	1609·3296
28	8·534	56	17·068				

To convert sea measurements of knots into English miles, multiply the knots by 1,1516.

Digitized by Google

METRES AND THEIR EQUIVALENTS IN FEET AND INCHES.

Metres.	Feet.	Inches:	Metres.	Feet.	Inches.	Metres.	Feet.	Inches.
1	3	3·3704	38	124	8·0764	74	242	9·4119
2	6	6·7409	39	127	11·4468	75	246	0·7824
3	9	10·1113	40	131	2·8173	76	249	4·1528
4	13	1·4817	41	134	6·1877	77	252	7·5233
5	16	4·8522	42	137	9·5581	78	255	10·8937
6	19	8·2226	43	141	0·9286	79	259	2·2641
7	22	11·5930	44	144	4·2990	80	262	5·6345
8	26	2·9634	45	147	7·6694	81	265	9·0049
9	29	6·3334	46	150	11·0399	82	269	0·3754
10	32	9·7043	47	154	2·4103	83	272	3·7458
11	36	1·0747	48	157	5·7807	84	275	7·1163
12	39	4·4452	49	160	9·1512	85	278	10·4867
13	42	7·8156	50	164	0·5216	86	282	1·8571
14	45	11·1860	51	167	3·8920	87	285	5·2276
15	49	2·5565	52	170	7·2625	88	288	8·5980
16	52	5·9269	53	173	10·6329	89	291	11·9684
17	55	9·2973	54	177	2·0033	90	295	3·3389
18	59	0·6678	55	180	5·3737	91	298	6·7093
19	62	4·0382	56	183	8·7442	92	301	10·0797
20	65	7·4086	57	187	0·1146	93	305	1·4502
21	68	10·7791	58	190	3·4850	94	308	4·8206
22	72	2·1495	59	193	6·8555	95	311	8·1910
23	75	5·5199	60	196	10·2259	96	314	11·5615
24	78	8·8904	61	200	1·5963	97	318	2·9319
25	82	0·2608	62	203	4·9668	98	321	6·3023
26	85	3·6312	63	206	8·3372	99	324	9·6728
27	88	7·0017	64	209	11·7076	100	328	1·0432
28	91	10·3721	65	213	3·0781	200	656	2·086
29	95	1·7425	66	216	6·4485	300	984	3·129
30	98	5·1129	67	219	9·8189	400	1312	4·173
31	101	8·4834	68	223	1·1894	500	1640	5·216
32	104	11·8538	69	226	4·5598	600	1968	6·259
33	108	3·2242	70	229	7·9302	700	2296	7·302
34	111	6·5947	71	232	11·3007	800	2624	8·345
35	114	9·9651	72	236	2·6711	900	2952	9·389
36	118	1·3355	73	239	6·0415	1000	3280	10·432
37	121	4·7059						

Digitized by Google

METRIC WEIGHTS AND ENGLISH EQUIVALENTS.

Kilogr'ms.	Lbs.	Kilogr'ms.	Lbs.	Kilogr'ms.	Lbs.
1	2·2046	38	83·7756	75	165·3466
2	4·4092	39	85·9802	76	167·5512
3	6·6139	40	88·1848	77	169·7559
4	8·8185	41	90·3895	78	171·9605
5	11·0231	42	92·5941	79	174·1651
6	13·2277	43	94·7987	80	176·3697
7	15·4324	44	97·0034	81	178·5743
8	17·6370	45	99·2079	82	180·7789
9	19·8416	46	101·4123	83	182·9836
10	22·0462	47	103·6172	84	185·1882
11	24·2508	48	105·8218	85	187·3928
12	26·4554	49	108·0264	86	189·5974
13	28·6601	50	110·2311	87	191·8020
14	30·8647	51	112·4357	88	194·0067
15	33·0693	52	114·6403	89	196·2113
16	35·2739	53	116·8499	90	198·4159
17	37·4786	54	119·0495	91	200·6205
18	39·6832	55	121·2542	92	202·8251
19	41·8878	56	123·4588	93	205·0298
20	44·0924	57	125·6634	94	207·2344
21	46·2970	58	127·8680	95	209·4390
22	48·5017	59	130·0727	96	211·6431
23	50·7063	60	132·2773	97	213·8482
24	52·9109	61	134·4819	98	216·0529
25	55·1155	62	136·6865	99	218·2575
26	57·3202	63	138·8911	100	220·4621
27	59·5248	64	141·0958	200	440·9243
28	61·7294	65	143·3004	300	661·3864
29	63·9340	66	145·5050	400	881·8485
30	66·1386	67	147·7096	500	1102·3106
31	68·3433	68	149·9142	600	1322·7728
32	70·5479	69	152·1189	700	1543·2349
33	72·7525	70	154·3235	800	1763·6970
34	74·9571	71	156·5281	900	1984·1591
35	77·1617	72	158·7327	1000	2204·6213
36	79·3664	73	160·9374	1016	2239·8952
37	81·5709	74	163·1419		

Digitized by Google

Equivalent Square Measure.

English to Metric.

	Square inches to square centimetres	Square feet to square decimetres.	Square feet to square metres.	Square yards to square metres.
1 =	6·45148	9·29013	·0929013	·836112
2	12·90296	18·58026	·1858026	1·672224
3	19·35444	27·87039	·2787039	2·508336
4	25·80592	37·16052	·3716052	3·344448
5	32·25740	46·45065	·4645065	4·180560
6	38·70888	55·74078	·5574078	5·016672
7	45·16036	65·03091	·6503091	5·852784
8	51·61184	74·32104	·7432104	6·688896
9	58·06332	83·61117	·8361117	7·525008
10	64·51480	92·90130	·9290130	8·361120
11	70·96628	102·19143	1·0219143	9·197232
12	77·41776	111·48156	1·1148156	10·033344
13	83·86924	120·77169	1·2077169	10·869456
14	90·32072	130·06182	1·3006182	11·705568
15	96·77220	139·35195	1·3935195	12·541680
16	103·22368	148·64208	1·4864208	13·377792
17	109·67516	157·93221	1·5793221	14·213904
18	116·12664	167·22234	1·6722234	15·050016
19	122·57812	176·51247	1·7651247	15·886128
20	129·02960	185·80260	1·8580260	16·722240

Metric to English.

	Square centimetres to square inches.	Square decimetres to square feet.	Square metres to square feet.	Square metres to square yards.
1 =	·155003	·107641	10·7641	1·19601
2	·310006	·215282	21·5282	2·39202
3	·465009	·322923	32·2923	3 58803
4	·620012	·430564	43·0564	4·78404
5	·775015	·538205	53·8205	5·98005
6	·930018	·645846	64·5846	7·17606
7	1·085021	·753487	75·3487	8·37207
8	1·240024	·861128	86·1128	9·56808
9	1·395027	·968769	96·8769	10·76409
10	1·550030	1·076410	107·6410	11·96010
11	1·705033	1·184051	118·4051	13·15611
12	1·860036	1·291692	129·1692	14·35212
13	2·015039	1·399333	139·9333	15·54813
14	2·170042	1·506974	150 6974	16·74414
15	2·325045	1·614615	161·4615	17 94015
16	2·480048	1·722256	172·2256	19·13616
17	2·635051	1·829897	182·9897	20·33217
18	2·790054	1·937538	193 7538	21·52818
19	2·945057	2·045179	204·5179	22·72419
20	3·100060	2·152820	215·2820	23·92020

These equivalents can be used for larger or smaller numbers by placing the decimal points to correspond. For instance, 130 square inches = 838·6924 square centimetres (the decimal point in the number opposite 13 is moved one place to the right), or 1525 square yards = 1275·0708 square metres, the sum being found as follows :—

1500 = 1254·168
20 = 16·72224
5 = 4·18056

1525 = 1275·0708

Digitized by Google

Equivalent Cubic Measure.

English to Metric.

	Cubic inches to cubic centimetres	Cubic feet to cubic decimetres.	Cubic feet to cubic metres.	Cubic yards to cubic metres.
1=	16·387	28·3153	·028315	·76453
2	32·774	56·6306	.056631	1·52906
3	49·161	84·9459	.084946	2·29359
4	65·548	113·2612	·113261	3·05812
5	81·935	141·5765	·141576	3·82265
6	98·322	169·8918	·169892	4·58718
7	114·709	198·2071	·198207	5·35171
8	131·096	226·5224	·226522	6·11624
9	147·483	254·8377	·254838	6·88077
10	163·870	283·1530	·283153	7·64530
11	180·257	311·4683	·311468	8·40983
12	196·644	339·7836	·339783	9·17436
13	213·031	368·0989	·368099	9·93889
14	229·418	396·4142	·396414	10·70342
15	245·805	424·7295	·424729	11·46795
16	262·192	453·0448	·453045	12·23248
17	278·579	481·3601	·481360	12·99701
18	294·966	509·6754	·509675	13·76154
19	311·353	537·9907	·537991	14·52607
20	327·740	566·3060	·566306	15·29060

Metric to English.

	Cubic centimetres to cubic inches.	Cubic decimetres to cubic feet.	Cubic metres to cubic feet.	Cubic metres to cubic yards.
1=	·061025	·0353156	35·3156	1·308
2	·122050	·0706312	70·6312	2·616
3	·183075	·1059468	105·9468	3 924
4	·244100	·1412624	141·2624	5·232
5	·305125	·1765780	176·5780	6 540
6	·366150	·2118936	211·8936	7 848
7	·427175	·2472092	247·2092	9 156
8	·488200	·2825248	282·5248	10·464
9	·549225	·3178404	317·8404	11·772
10	·610250	·3531560	353·1560	13 080
11	·671275	·3884716	388·4716	14·388
12	·732300	·4237872	423·7872	15·696
13	·793325	·4591028	459·1028	17·004
14	·854350	·4944184	494·4184	18·312
15	·915375	·5297340	529·7340	19 620
16	·976400	·5650496	565·0496	20·928
17	1·037425	·6003652	600·3652	22·236
18	1·098450	·6356808	635·6808	23·544
19	1·159475	·6709964	670·9964	24·852
20	1·220500	·7063120	706·3120	26·160

The above table can be used for smaller or larger quantities, if desired, by changing the decimal points to correspond. For instance :—

·2 cubic inch =3·2774 cubic centimetres,
170· " " =2785·79 " "
2815 cubic yards=2152·15195 cubic metres ;

which is calculated as follows :—

2000 cubic yards=1529·060 " "
800 " " = 611·624 " "
15 " " = 11·46795 " "

2815 2152·15195

Digitized by Google

POUNDS PER SQUARE INCH WITH EQUIVALENT KILOS PER SQUARE CENTIMETRE.

Lbs. per sq. inch.	Kilos. per sq. cm.	Lbs. per sq. inch.	Kilos. per sq. cm.	Lbs. per sq. inch.	Kilos. per sq. cm.	Lbs. per sq. inch.	Kilos. per sq. cm.	Lbs. per sq. inch.	Kilos. per sq. cm.
1	·0703	35	2·460	69	4·850	103	7·241	137	9·632
2	·1406	36	2·530	70	4·921	104	7·312	138	9·702
3	·2109	37	2·601	71	4·991	105	7·382	139	9·772
4	·2812	38	2·671	72	5·061	106	7·452	140	9·843
5	·3515	39	2·741	73	5·131	107	7·522	141	9·913
6	·4218	40	2·812	74	5·202	108	7·593	142	9·983
7	·4921	41	2·882	75	5·272	109	7·663	143	10·054
8	·5624	42	2·952	76	5·342	110	7·733	144	10·124
9	·6327	43	3·022	77	5·413	111	7·804	145	10·194
10	·7030	44	3·093	78	5·483	112	7·874	146	10·264
11	·7733	45	3·163	79	5·553	113	7·944	147	10·335
12	·8436	46	3·233	80	5·624	114	8·015	148	10·405
13	·9140	47	3·304	81	5·694	115	8·085	149	10·475
14	·9843	48	3·374	82	5·764	116	8·155	150	10·546
15	1·0546	49	3·444	83	5·834	117	8·226	155	10·897
16	1·1248	50	3·515	84	5·905	118	8·296	160	11·249
17	1·1952	51	3·585	85	5·975	119	8·366	165	11·600
18	1·265	52	3·655	86	6·045	120	8·436	170	11·952
19	1·335	53	3·725	87	6·116	121	8·507	175	12·303
20	1·406	54	3·796	88	6·186	122	8·577	180	12·655
21	1·476	55	3·866	89	6·256	123	8·647	185	13·006
22	1·546	56	3·936	90	6·327	124	8·718	190	13·358
23	1·616	57	4·007	91	6·397	125	8·788	195	13·710
24	1·687	58	4·077	92	6·467	126	8·858	200	14·061
25	1·757	59	4·147	93	6·537	127	8·929	210	14·76
26	1·827	60	4·218	94	6·608	128	8·999	220	15·46
27	1·898	61	4·288	95	6·678	129	9·069	230	16·16
28	1·968	62	4·358	96	6·748	130	9·140	240	16·87
29	2·038	63	4·428	97	6·819	131	9·210	250	17·57
30	2·109	64	4·499	98	6·889	132	9·280	260	18·27
31	2·179	65	4·569	99	6·959	133	9·350	270	18·98
32	2·249	66	4·639	100	7·030	134	9·421	280	19·68
33	2·319	67	4·710	101	7·101	135	9·491	290	20·38
34	2·390	68	4·780	102	7·171	136	9·561	300	21·09

Digitized by Google

KILOS PER SQUARE CENTIMETRE WITH EQUIVALENT POUNDS PER SQUARE INCH.

Kilos. per sq. cm.	Lbs. per square inch.	Kilos. per sq. cm.	Lbs. per square inch.	Kilos. per sq. cm.	Lbs. per square inch.	Kilos. per sq. cm.	Lbs. per square inch.
·1	1·422	3·1	44·091	6·1	86·761	9·1	129·431
·2	2·844	3·2	45·514	6·2	88·183	9·2	130·853
·3	4·266	3·3	46·936	6·3	89·606	9·3	132·275
·4	5·689	3·4	48·358	6·4	91·028	9·4	133·698
·5	7·111	3·5	49·781	6 5	92·450	9·5	135·120
·6	8·533	3·6	51·203	6·6	93·873	9·6	136·542
·7	9·956	3·7	52·625	6·7	95·295	9·7	137·965
·8	11·378	3·8	54·048	6·8	96·717	9·8	139·387
·9	12·800	3·9	55·470	6·9	98·140	9·9	140·809
1·0	14·223	4·0	56·892	7·0	99·562	10·0	142·232
1·1	15·645	4·1	58·315	7·1	100·984	10·5	149·343
1·2	17·067	4·2	59·737	7·2	102·407	11·0	156·455
1·3	18·490	4·3	61·159	7·3	103·829	11·5	163·566
1·4	19·912	4·4	62·582	7·4	105·251	12·0	170·678
1·5	21·334	4·5	64·004	7·5	106·674	12 5	177·790
1·6	22·757	4·6	65·426	7·6	108·096	13·0	184·901
1·7	24·179	4·7	66·849	7·7	109·518	13·5	192·013
1·8	25·601	4·8	68·271	7·8	110·940	14·0	199·124
1·9	27·024	4·9	69·693	7·9	112·363	14·5	206·236
2·0	28·446	5·0	71·116	8·0	113·785	15·0	213·348
2·1	29·868	5·1	72·538	8·1	115·207	15·5	220·459
2·2	31·291	5·2	73·960	8·2	116·630	16 0	227·571
2·3	32·713	5·3	75·382	8·3	118·052	16·5	234·682
2·4	34·135	5·4	76·805	8·4	119·474	17·0	241·794
2·5	35·558	5·5	78·227	8·5	120·897	17·5	248·906
2·6	36·980	5·6	79·649	8·6	122·319	18 0	256·017
2·7	38·402	5·7	81·072	8·7	123·741	18·5	263·129
2·8	39·824	5·8	82·494	8·8	125·164	19·0	270·240
2·9	41·247	5·9	83·916	8·9	126·586	19·5	277·352
	42·669	6·0	85·339	9·0	128·008	20·0	284·464

Digitized by Google

United States Coast and Geodetic Survey.
OFFICE OF
STANDARD WEIGHTS AND MEASURES.
T. C. MENDENHALL, SUPT.

Tables for Converting U. S. Weights and Measures.

METRIC TO CUSTOMARY.

LINEAR.					CAPACITY.					
	Metres to Inches.	Metres to Feet.	Metres to Yards.	Kilometres to Miles.		Millilitres or cub. Centim's to Fl'd Drams	Centi-litres to Fluid Ozs.	Litres to Quarts.	Deca-litres to Gallons.	Hectolitres to Bushels.
1=	39·3700	3·28083	1·093611	0·62137	1=	0·27	0·338	1·0567	2·6417	2·8377
2=	78·7400	6·56167	2·187222	1·24274	2=	0·54	0·676	2·1134	5·2834	5·6755
3=	118·1100	9·84250	3·280833	1·86411	3=	0·81	1·014	3·1700	7·9251	8·5132
4=	157·4800	13·12333	4·374444	2·48548	4=	1·08	1·353	4·2267	10·5668	11·3510
5=	196·8500	16·40417	5·468056	3·10685	5=	1·35	1·691	5·2834	13·2085	14·1887
6=	236·2200	19·68500	6·561667	3·72822	6=	1·62	2·029	6·3401	15·8502	17·0265
7=	275·5900	22·96583	7·655278	4·34959	7=	1·89	2·367	7·3968	18·4919	19·8642
8=	314·9600	26·24667	8·748889	4·97096	8=	2·16	2·705	8·4535	21·1336	22·7019
9=	354·3300	29·52750	9·842500	5·59233	9=	2·43	3·043	9·5101	23·7753	25·5397

SQUARE.					WEIGHT.				
	Sq. Centi-metres to Sq. Inches.	Sq. Metres to Sq. Feet.	Sq. Metres to Sq. Yards.	Hectares to Acres.		Milli-grammes to Grains.	Kilogrammes to Grains.	Hectogr'mes to Ounces Avoirdupois.	Kilogrammes to Pounds Avoirdupois.
1=	0·1550	10·764	1·196	2·471	1=	0·01543	15432·36	3·5274	2·20462
2=	0·3100	21·528	2·392	4·942	2=	0·03086	30864·71	7·0548	4·40924
3=	0·4650	32·292	3·588	7·413	3=	0·04630	46297·07	10·5822	6·61387
4=	0·6200	43·055	4·784	9·884	4=	0·06173	61729·43	14·1096	8·81849
5=	0·7750	53·819	5·980	12·355	5=	0·07716	77161·78	17·6370	11·02311
6=	0·9300	64·583	7·176	14·826	6=	0·09259	92594·14	21·1644	13·22773
7=	1·0850	75·347	8·372	17·297	7=	0·10803	108026·49	24·6918	15·43236
8=	1·2400	86·111	9·568	19·768	8=	0·12346	123458·85	28·2192	17·63698
9=	1·3950	96·875	10·764	22·239	9=	0·13889	138891·21	31·7466	19·84160

Digitized by Google

CUBIC. WEIGHT.—CONTINUED.

	Cub. Centimetres to Cub. In.	Cub. Decimet's to Cub. Inches.	Cubic Metres to Cubic Feet.	Cub. Metres to Cub. Yds.		Quintals to Pounds Avoirdupois.	Milliers or Tonnes to Pounds Avoirdupois.	Kilogrammes to Ounces Troy.
1=	0·0610	61·023	35·314	1·308	1=	220·46	2204·6	32·1507
2=	0·1220	122·047	70·629	2·616	2=	440·92	4409·2	64·3015
3=	0·1831	183·070	105·943	3·924	3=	661·39	6613·9	96·4522
4=	0·2441	244·094	141·258	5·232	4=	881·85	8818·5	128·6030
5=	0·3051	305·117	176·572	6·540	5=	1102·31	11023·1	160·7537
6=	0·3661	366·140	211·887	7·848	6=	1322·77	13227·7	192·9044
7=	0·4272	427·164	247·201	9·156	7=	1543·24	15432·4	225·0552
8=	0·4882	488·187	282·516	10·464	8=	1763·70	17637·0	257·2059
9=	0·5492	549·210	317·830	11·771	9=	1984·16	19841·6	289·3567

By the concurrent action of the principal governments of the world an International Bureau of Weights and Measures has been established near Paris. Under the direction of the International Committee two ingots were cast of pure platinum-iridium in the proportion of 9 parts of the former to 1 of the latter metal. From one of these a certain number of kilogrammes were prepared, from the other a definite number of metre bars. These standards of weight and length were intercompared, without preference, and certain ones were selected as International prototype standards. The others were distributed by lot, in September, 1889, to the different governments, and are called National prototype standards. Those apportioned to the United States were received in 1890 and are in the keeping of this office.

The metric system was legalized in the United States in 1866.

The International Standard Metre is derived from the Metre des Archives, and its length is defined by the distance between two lines at 0° Centigrade on a platinum-iridium bar deposited at the International Bureau of Weights and Measures.

The International Standard Kilogramme is a mass of platinum-iridium deposited at the same place, and its weight in vacuo is the same as that of the Kilogramme des Archives.

The litre is equal to a cubic decimetre, and it is measured by the quantity of distilled water which, at its maximum density, will counterpois the standard kilogramme in a vacuum, the volume of such quantity of water being, as nearly as has been ascertained, equal to a cubic decimetre.

Digitized by Google

United States Coast and Geodetic Survey.
OFFICE OF
STANDARD WEIGHTS AND MEASURES.
T. C. MENDENHALL, SUPT.

Tables for Converting U. S. Weights and Measures.

CUSTOMARY TO METRIC.

LINEAR.

	Inches to Milli-metres.	Feet to Metres.	Yards to Metres.	Miles to Kilometres.
1=	25·4001	0·304801	0·914402	1·60935
2=	50·8001	0·609601	1·828804	3·21869
3=	76·2002	0·914402	2·743205	4·82804
4=	101·6002	1·219202	3·657607	6·43739
5=	127·0003	1·524003	4·572009	8·04674
6=	152·4003	1·828804	5·486411	9·65608
7=	177·8004	2·133604	6·400813	11·26543
8=	203·2004	2·438405	7·315215	12·87478
9=	228.6005	2·743205	8·229616	14·48412

CAPACITY.

	Fluid drams to millilitres or cub. centimetres	Fluid Ounces to Millilitres.	Quarts to Litres.	Gallons to Litres.
1=	3·70	29·57	0·94636	3·78543
2=	7·39	59·15	1·89272	7·57087
3=	11·09	88·72	2·83908	11·35630
4=	14·79	118·29	3·78543	15·14174
5=	18·48	147·87	4·73179	18·92717
6=	22·18	177·44	5·67815	22·71261
7=	25·88	207·02	6·62451	26·49804
8=	29.57	236·59	7·57087	30·28348
9=	33·27	266·16	8·51723	34·06891

SQUARE.

	Sq. Inches to Square Centim'tres	Square Feet to Square Decimetres.	Square Yards to Square Metres.	Acres to Hectares.
1=	6·452	9·290	0·836	0·4047
2=	12·903	18·581	1·672	0·8094
3=	19·355	27·871	2·508	1·2141
4=	25·807	37·161	3·344	1·6187
5=	32·258	46·452	4·181	2·0234
6=	38·710	55·742	5·017	2·4281
7=	45·161	65·032	5·853	2·8328
8=	51·613	74·323	6·689	3·2375
9=	58·065	83·613	7·525	3·6422

WEIGHT.

	Grains to Milli-grammes.	Avoirdupois Ounces to Grammes.	Avoirdupois Pounds to Kilogram'es.	Troy Ounces to Grammes.
1=	64·7989	28·3495	0·45359	31·10348
2=	129·5978	56·6991	0·90719	62·20696
3=	194·3968	85·0486	1·36078	93·31044
4=	259·1957	113·3981	1·81437	124·41392
5=	323·9946	141·7476	2·26796	155·51740
6=	388·7935	170·0972	2·72156	186·62088
7=	453·5924	198·4467	3·17515	217·72437
8=	518·3914	226·7962	3·62874	248·82785
9=	583·1903	255·1457	4·08233	279·93133

Digitized by Google

CUBIC.

	Cubic In. to Cubic Centim'tres	Cubic Feet to Cubic Metres.	Cubic Yards to Cubic Metres.	Bushels to Hectolitres.
1=	16·387	0·02832	0·765	0·35239
2=	32·774	0·05663	1·529	0·70479
3=	49·161	0·08495	2·294	1·05718
4=	65·549	0·11327	3·058	1·40957
5=	81·936	0·14158	3·823	1·76196
6=	98·323	0·16990	4·587	2·11436
7=	114·710	0·19822	5·352	2·46675
8=	131·097	0·22654	6·116	2·81914
9=	147·484	0·25485	6·881	3·17154

1 Gunter's chain	=	20·1168	metres.
1 sq. statue mile	=	259·000	hectares.
1 fathom	=	1·829	metres.
1 nautical mile	=	1853·25	metres.
1 foot = 0·304801 metre,		9·4840158	log.
1 avoir. pound	=	453·5924277	gram.
15432·35639 grains	=	1	kilogramme.

The only authorized material standard of customary length is the Troughton scale belonging to this office, whose length at 59°.62 Fahr. conforms to the British standard. The yard in use in the United States is therefore equal to the British yard.

The only authorized material standard of customary weight is the Troy pound of the Mint. It is of brass of unknown density, and therefore not suitable for a standard of mass. It was derived from the British standard Troy pound of 1758 by direct comparison. The British Avoirdupois pound was also derived from the latter, and contains 7000 grains Troy.

The grain Troy is therefore the same as the grain Avoirdupois, and the pound Avoirdupois in use in the United States is equal to the British pound Avoirdupois.

The British gallon = 4.54346 litres.

The British bushel = 36.3477 litres.

The length of the nautical mile given above and adopted by the U. S. Coast and Geodetic Survey many years ago, is defined as that of a minute of arc of a great circle of a sphere whose surface equals that of the earth (Clark's Spheroid of 1866.)

WASHINGTON, D. C. NOVEMBER, 1891.

Digitized by Google

METRIC CONVERSION TABLES.

According to Latimer Clark's "Metric Measures," which gives one cubic inch of distilled water, freed from air at 62 degrees Fahrenheit, barometer thirty inches, as 252.28599 grains; or one cubic foot as 62.2786 pounds.

Millimeters x .039371 = inches.
Millimeters ÷ 25.4 = inches.
Centimeters x .393708 = inches.
Centimeters ÷ 2.5399 = inches.
Meters x 39.37079 = inches.
Meters x 3.280899 = feet.
Meters x 1.09363 = yards.
Kilometers x .62138 = miles.
Kilometers ÷ 1.6093 = miles.
Kilometers x 3280.899 = feet.
Square Millimeters x .00155 = square inches.
Square Millimeters ÷ 645.137 = square inches.
Square Centimeters x .155006 = square inches.
Square Centimeters ÷ 6.4514 = square inches.
Square Meters x 10.7643 = square feet.
Square Kilometers x 247.114 = acres.
Hectare x 2.47114 = acres.
Cubic Centimeters ÷ 16.3862 = cubic inches.
Cubic Centimeters ÷ 3.5520 = fl. drachms
Cubic Centimeters ÷ 28.416 = fluid oz.
} Imperial gallon of water at 62° Fahr.= 277.463 cubic inches.
Cubic Metres x 35.31658 = cubic feet.
Cubic Meters x 1.30802 = cubic yards.
Cubic Meters x 264.2 = gallons (231 cubic inches.)
Liters x 61.0364 = cubic inches.

Digitized by Google

Liters x 35.1968 = fluid ounces.
Liters x .2642 = gallons (231 cubic inches.)
Liters ÷ 3.785 = gallons (231 cubic inches.)
Liters ÷ 28.311 = cubic feet.
Hectoliters x 3.5322 = cubic feet.
Hectoliters x 2.84 = bushels (2150.42 cubic inches.)
Hectoliters x .131 = cubic yards.
Hectoliters x 26.42 = gallons (231 cubic inches.)
Grammes x 15.43235 = grains.
Grammes × 981.17 = dynes.
Grammes ÷ 28.416 = fluid oz. (Imp. gal. at 62° Fahr., 277.463 cubic inches.)
Grammes ÷ 28.349 = ounces avoirdupois. (Water at 62° Fahr.)
Grammes per cubic cent. ÷ 27.7 = lbs. per cubic inch.
Joule x .73719 = foot pounds.
Kilogrammes x 2.204621 = pounds avoirdupois.
Kilogrammes x 35.2739 = ounces avoirdupois.
Kilogrammes ÷ 1016.05 = tons (2240 lbs.)
Kilogrammes ÷ 907.18 = tons (2000 lbs.)
Kilogramme per square cent. x 14.2228 = lbs. per sq. in.
Kilogrammeters x 7.2331 = foot lbs.
Kilo. per meter x .67196 = lbs. per foot.
Kilo. per cubic meter x .06243 = lbs. per cubic foot.
Kilo. per cheval x 2.235 = lbs. per horse power.
Kilo. Watts x 1.3404 = horse power.
Watts ÷ 746.071 = horse power.
Watts x .7372 = foot pounds per second.
Kilogram Calories x 3.968 = B. T. U.
Cheval vapeur x .98634 = horse power.
(Centigrade x 1.8) + 32 = deg. Fahr. (Temperature.)
Franc x .193 = dollars. [Exchange as per Treasury circular.
Gravity Paris = 980.94 centimeters per second.
Tons of 2240 lbs. x 1.016 = tonnes.
Tons of 2000 lbs. x .9071 = tonnes.
Square inches x 645.137 = square millimeters.
Lbs. per square inch x .000701 = kilos per square millimeters.

Digitized by Google

METRIC CONVERSION TABLE.—Continued.

Square miles x 2.590 = square kilometers.

Quarts dry measure x 1.101 = liters.

Quarts liquid or wine measure x .9461 = liters.

Foot pounds x .1383 = kilogrammes per meter.

Thousands of pounds per square inch x 0.703 = kilogrammes per square millimeter.

Pounds per square foot x 4.8826 = kilogrammes per square meter.

Pounds per cubic foot x 16.02 = kilogrammes per cubic meter.

Tonnes x .9842 = tons of 2240 lbs.

Tonnes x 1.1023 = tons of 2000 lbs.

Liters (one cubic decimeter) x 61.036 = cubic inches.

Liters x .908 = quarts, dry measure.

Liters x 1.0566 = quarts, liquid or wine measure.

Kilogrammes per square millimeter x 1422.28 = pounds per square inch.

Kilogrammes per square meter x .20481 = pounds per square foot.

Kilogrammes per cubic meter x .06243 = pounds per cubic foot.

Digitized by Google

METRIC CONVERSION TABLE.—Continued.

Kilowatts.	Multiply.	Divide.	Logarithm.
" into horse-power,..........	1.3404	.746	0.12722
" into foot-pounds, per second,	737.2	....	2.86758
" into foot-pounds, per minute,	44,232	....	4.64573
" into kilogram-meters, per s.	101.919	....	2.00826
" into volt-amperes, per second	1000	....	3.00000
" into commercial 'units,' per h.	1	....	0.00000

Mils.	Multiply.	Divide.	Logarithm.
" into Micromillimetres,...	25399.5	....	4.40483
" into microns or micrometres	25.3995	....	1.40483

Square Mils.			
" into square inches,.....	....	1,000,000	$\bar{6}.00000$
" into square millimetres,.	.0006451	1550.059	$\bar{4}.80965$

Circular Mils.			
" into square inches,.....	....	1,273,240	$\bar{7}.89509$
" into square millimetres,	.0005067	1973.6	$\bar{4}.70474$

Cube Mils.			
" into cube inches,......	....	1,000,000,000	$\bar{9}.00000$
" into cube millimetres,..	.00001639	61027.05	$\bar{5}.21448$
" into grains (water 62° F.)	....	3,963,756	$\bar{7}.40189$

WATT. The B. A. unit rate of work or unit of power $=$ $\frac{1}{746}$ horse-power $= 10^7$ absolute units of work, or 10 million ergs per second $=$ 1 volt-ampere, or 1 joule per second,

(1 true watt $=$ 1.0136 B. A. Watts.)

$$\text{Watts} = \text{volts} \times \text{amperes} = \text{amperes}^2 \times \text{ohms} = \frac{\text{volts}^2}{\text{ohms.}}$$

Watt x seconds = joules.	Logarithm.
One watt raises .24046 grammes of water 1 °C. per sec.	$\bar{1}.38105$
" " " 6.6796 grains of water 1° F. per sec.	0.82475

Watts.	Multiply.	Divide	Logarithm.
" into horse-power,..........	.001340	746.071	$\bar{3}.12722$
" into French force-de-cheval,	.001359	735.88	$\bar{3}.13319$
" into ergs per second,......	10^7	....	7.00000
" into foot-pounds per minute	44.2317	....	1.64573
" into foot-pounds per second	.7372	1.3565	$\bar{1}.86758$

Digitized by Google

Watts.	Multiply	Divide.	Logarithm.
" into kilogram-metres, per s.	.10192	9.8177	1.00826
" into joules per second,.....	1	....	....
" into gramme calories per s.	.24046	4.1586	$\bar{1}$.38105
" into British thermal units, per second,......	.000954	1048	$\bar{4}$.97966

Watt-Hours.			
" into horse-power hours,....	.0013403	746.071	$\bar{3}$.12722
" into foot-pounds,.	2653.9	....	3.42389
" into British thermal units,	3.4352	....	0.53596
" into gramme calories,.....	865.67	....	2.93735
" into joules,...............	3600	....	3.55630
" into ergs,........	3.6×10^{10}	....	10.55630
" into Board of Trade electrical units,...............	.001	1000	$\bar{3}$.00000

HORSE-POWER. The practical unit of power = 746.071 watts = 33,000 lbs. raised 1 foot per minute.

$$\text{Electrical horse-power} = \frac{\text{amperes} \times \text{volts}}{746} = \frac{\text{amperes}^2 \times \text{ohms.}}{746}$$

Horse-Power.	Multiply.	Divide.	Logarithm.
" into foot-pounds per minute,	33000	....	4.51851
" into foot-pounds per second,	550	....	2.74036
" into foot-tons per minute,..	14.7321	...	1.16826
" into foot-tons per hour,....	883.928	....	2.94642
" into kilogram-metres per m.	4562	....	3.65916
" into kilogram-metres per s.	76.0389	....	1.88104
" (electrical) into kilowatts...	.7461	....	$\bar{1}$.87278
" into watts,................	746.071	...	2.87278
" into joules or volt-amperes, per second,.............	746.071	....	2.87278
" into ergs per second,.......	7.46×10^9	....	9.87278
" into gramme-cals. or therms per second,............	179.40	....	2.25383
" into British thermal units, per second,.............	.71193	1.4046	$\bar{1}$.85244
" into British thermal units, per minute,............	42.7156	...	1.63059
" into gallons water raised 1° F. per minute,..........	4.2716	....	0.63059
" into French horse-power,..	1.01385	....	0.00597

Digitized by Google

Horse-Power-Hour.	Multiply.	Divide.	Logarithm.
" into foot-tons, ...	833.93	....	2.94642
" into foot-pounds, ...	1,980,000	....	6.29667
" into kilogram-metres, ...	273740	....	5.43734
" into large calories, (therm. equiv.)	645.85	....	2.81013
" into ergs, ...	2.6859×10^{13}	....	13.42908
" joules, ...	2685860	....	6.42908
" into watt-hours, ...	746.071	....	2.87278
" into Board of Trade electrical units, ...	.7461	1.34035	$\bar{1}.87278$

HEAT OF THE ELECTRIC CURRENT. The heat generated by the passage of an electric current (in a metallic circuit without self-induction) is proportional to the quantity of electricity which has passed in coulombs, multiplied by the fall of potential in volts, or is equal to $\frac{\text{coulombs} \times \text{volts}}{4.1586}$ in therms.

The heat in gramme-calories, or therms, per second=

$$\frac{\text{amperes}^2 \times \text{ohms}}{4.1586} = \frac{\text{volts}^2}{\text{ohms} \times 4.1586} = \frac{\text{volts} \times \text{amperes}}{4.1586} = \frac{\text{watts*}}{4.1586}$$

*These should be true ohms and volts. The heat per second is proportional to C^2 R, or the square of the current multiplied by the resistance, as above shown. It varies as the square of the current. It also varies as the square of the E. M. F., or difference of potential, for these two functions always vary in the same proportion.

Heat.	Multiply.	Divide.	Logarithm.
Total heat in t seconds, in gramme-calories or therms = volts × amperes × t ×	.2405	4.1586	$\bar{1}.38105$
" in kilogram-calories = V × A × t ×	.000240	4158.6	$\bar{4}.38105$
" in British therm. units, = V × A × t ×	.000954	1048	$\bar{4}.97966$
" in lbs. of water 1° C. = V × A × t ×	.000530	1886.3	$\bar{4}.72438$

HEAT OF EVAPORATION. The units of heat of evaporation are 1 lb. of water at 212° F. evaporated into steam at normal pressure = 966.1 British thermal units, or 1 kilogramme of water at 100° C. evaporated = 536.7 kilogram-calories.

Digitized by Google

Absolute Zero of Heat. The absolute zero = –274° C., or –461.2° F.

Atmosphere. English normal = 14.7 lbs. per square inch = 29.929 inches, or 760.18 millimetres of mercury at 32° F.

Atmospheres.	Multiply.	Divide.	Logarithm.
" into pounds per square inch,	14.7	....	1.16732
" into pounds per circular inch,	11.545	....	1.06239
" into pounds per square foot,	2116.8	....	3.32568
" into pounds per circ'lr foot,	1662.5	....	3.22077
" into cwts. per square foot,.	18.900	....	1.27646
" into cwts. per circular foot,	14.844	....	1.17155
" into cwts. per square inch,.	.1312	7.62	$\bar{1}$.11810
" into tons per square inch,..	.00656	152.38	$\bar{3}$.81707
" into tons per square foot,..	.9450	1.058	$\bar{1}$.97543
" into tons per circular foot,.	.7422	1.347	$\bar{1}$.87052
" into kilograms per square centimetre,.............	1.0335	....	0.01433
" into inches of mercury at 32° F.,................	29.929	...	1.47610
" into feet head of water 62° F	33.9892	....	1.53134
" into metres head of water 4° C.,.................	10.3597	....	1.01535

Atmosphere. French normal = 760 millimetres, or 29.922 inches of mercury at 0° C. = 14.696 lbs. per sq. inch.

French Atmospheres.	Multiply.	Divide.	Logarithm.
" into kilograms per square centimetre,.............	1.0333	....	0.01422
" into grammes per circular centimetre,........	811.55	....	2.90931
" into grammes per square millimetre,.............	10.333	....	1.01422
" into metres head of water, 4° C.,.................	10.345	....	1.01476
" into pounds per square inch,	14.696	....	1.16721
" into dynes per square centimetre,.................	1013600	....	6.00587

Digitized by Google

USEFUL EQUATIONS FOR CONVERSION OF U. S. CUSTOMARY MEASURES TO METRIC EQUIVALENTS.

THE FOLLOWING DATA IS FROM THE MECHANICAL ENGINEERS' REFERENCE BOOK BY NELSON FOLEY.

In.	× 25.4	= m-m.	m-m.	×	.0393704	= ins.
"	× 2.54	= c-m.	"	×	.0032808	= ft.
"	× .0254	= m.	c-m.	×	.393704	= ins.
Ft.	× 30.4797	= c-m.	"	×	.0328087	= ft.
"	× .30479	= m.	m.	×	39.3704	= ins.
Yards	× .91497	= m.	"	×	3.28087	= ft.
Miles	× .86842	= knots.	"	×	1.0736	= yds.
"	× 1.6093	= km.	km.	×	.62138	= miles.
Knots	× 1.1515	= miles.	"	×	.5396	= knots.
"	× 1.8531	= km.				

SQUARE.

British System.

144	square inches	= 1 square foot.
183.35	circular "	= 1 " "
9	square feet	= 1 square yard.
3,097,600	" yards	= 1 " mile.

Metric System.

100	square millimetres,	= 1 square c-m.
100	" centimetres,	= " d c-m.
100	" decimetres,	= 1 " metre.
10,000	" centimetres,	= 1 " metre.

Digitized by Google

Useful Equations.

Square inches	×	645.14476	=	sq.	millimetres.
" "	×	6.45144	=	"	centimetres.
" feet	×	929.0088	=	"	"
" "	×	.0929	=	"	metres.
" yards	×	.83611	=	"	"
" millimetres	×	.00155	=	"	inches.
" centimetres	×	.155002	=	"	"
" "	×	.001076	=	"	feet.
" metres	×	10.7641	=	"	"
" "	×	1.196	=	"	yards.

CUBIC AND CAPACITY.

British System.

	1,728 cub. ins.	=	1 cub. ft.	=	6.23208 gallons.	
	"	=	"	=	7.4805 A. "	
	27 cub. ft.	=	1 cub. yd.			
Liquids.	4 gills	=	1 pint	=	34.659	cub. in.
	2 pints	=	1 quart	=	69.318	"
	4 quarts	=	1 gallon	=	277.274	"
	1 gallon			=	.16046	cub. ft.
	8 gallons	=	1 bushel	=	1.28368	"
	1 American gallon			=	231.	cub. in.
	1 American gallon			=	.13368	cub. ft.

Metric System.

1,000 cub. m-m.	=	1 cub. c-m.			
1,000 " c-m.	=	1 " d c-m.	=	1 litre.	
1,000 " d c-m. / 1,000,000 " c-m.	=	1 " m.	=	1,000 "	

Liquids.	1 litre	=	1 cub. decimetre	=	1,000 cub. c-m.		
	1,000 litres	=	1 cub. metre.				
	10 centilitres	=	1 decilitre	=	100 cub. c-m.		
	10 decilitres	=	1 litre	=	1,000 "	=	1 cub. d c-m.
	10 litres	=	1 decalitre	=	10,000 "	=	10 "
	100 "	=	1 hectolitre	=	100,000 "	=	100 "
	1,000 "	=	1 kilolitre	=	1 cub. metre	=	1,000 "

Digitized by Google

Useful Equations.

Cub. ins.	×	16.3865	=	cub. c-m.
" "	×	.016386	=	" d c-m.
" ft.	×	.028316	=	" m.
" yds.	×	.76453	=	" "
" c m.	×	.061025	=	" ins.
" d c-m.	×	61.02522	=	" "
" m.	×	35.3156	=	" ft.
" "	×	1.308	=	" yds.
" "	×	6.23208	=	Br. gallons.
" "	×	7.4805	=	A. "
Pints	×	.5679	=	litres.
Quarts	×	1.1359	=	"
Br. gallons	×	4.5436	=	"
" "	×	1.20032	=	A. gallons.
" "	×	.16046	=	cub. ft.
A. "	×	3.7853	=	litres.
" "	×	.8331	=	Br. gallons.
" "	×	.13368	=	cub. ft.
Litres, "	×	.035315	=	" "
" "	×	61.02524	=	" ins.
" "	×	.2201	=	Br. gallons.
" "	×	.2642	=	A. "
" "	×	.8804	=	quarts.
" "	×	1.7608	=	pints.

WEIGHT.

British System, (Avoirdupois.)

16 drachms or 437½ grains. } = 1 ounce.
16 ounces = 1 pound.
14 pounds = 1 stone.
28 " = 1 quarter.
4 qr. = 112 lbs. = 1 hundred-weight.
20 cwt. = 2,240 lbs. = 1 ton.
1 U. S. short cwt. = 100 lbs.
20 " " " = 2,000 " = 1 U. S. short ton.

Abbreviations.
oz. for ounces
lbs. " pounds
st. " stone.
qr. " quarter.
cwt. " hundred-wgt.
T. " tons.

Digitized by Google

METRIC SYSTEM.

1,000 grammes	= 1 kilogramme.	Abbreviations. g.	for grammes.
100 kilogrs	= 1 quintal.	kg.	" kilogrammes.
10 quintals / 1,000 kilogrs.	= 1 metric ton.	q.	" metric quintals
		t.	" " tons.

1 gramme = 10 decigrammes.
1 " = 100 centigrammes.
10 grammes = 1 dekagramme.
100 " = 1 hectogramme.
1 metric ton = weight of 1 cub. m. of water at 39.1° F., 4° C.
1 litre of water weighs 1 kg. or 1,000 grammes.

USEFUL EQUATIONS.

Ounces	×	28.34954	=	grammes.
Pounds	×	453.59265	=	"
"	×	.45359	=	kilos.
Cwt.	×	50.80241	=	"
"	×	.50803	=	quintals.
"	×	1.12	=	short cwt.
Short cwt.	×	45.3597	=	kilos.
"	×	.89285	=	cwts.
"	×	.4536	=	quintals.
Tons	×	1.01604	=	metric ton.
"	×	10.1604	=	quintals.
"	×	1016.047	=	kilos.
"	×	1.12	=	short tons.
Short tons	×	.8928	=	Br. tons.
" "	×	.9071	=	metric ton.
Grammes	×	.03527	=	oz.
Kilos	×	2.2046	=	lbs.
"	×	.01968	=	cwts.
"	×	.0009842	=	tons.
Quintals	×	220.4621	=	lbs.
"	×	1.9684	=	cwts.
"	×	.09842	=	tons.
"	×	2.2046	=	short cwt.
"	×	.11023	=	short tons.
Metric ton	×	.9842	=	tons.
" "	×	1.1023	=	short tons.

Digitized by Google

PRESSURE AND STRESS.

British Units.	Metric Units.
Tons per square inch.	kg. per square c-m.
Lbs. " "	" " m-m.
Oz. " "	" " m.
Lbs. " foot.	Atmospheres.
Atmospheres.	* c-m. of mercury.
*Inches of mercury.	* " water.
* " " water.	* Metres of water.
*Feet " "	

* The intensity of pressure capable of balancing a column of the stated height.

Note.—It is usual to compare an atmosphere to a column of mercury either at 32° F. or at 62°, the ordinary temperature of 62° is preferred here, the mercury column is then 30 inches high or 76.2 centimetres. If the temperature of 32° is desired, the column is 29.922 inches or 76 centimetres.

The water column is also taken at 62°, in practice the differences are not worth considering.

1,000 pounds per square inch = 0.703 Kilogrammes per square Millimetres.

1 Kilogramme per square Millimetre = 1422.3 pounds per square inch, the thickness of a tube or cylinder to withstand a given pressure is equal to the normal pressure per square inch multiplied by the internal radius in inches of the tube or cylinder and the product divided by the working stress per square inch in tension of the material.

Digitized by Google

Useful Equations.

Lbs. per square inch	×	2.0408	=	ins. of mercury.
“ “	×	5.1836	=	c-m. “
“ “	×	27.711	=	ins. of water.
“ “	×	2.31	=	ft. “
“ “	×	.06802	=	Atmospheres.
“ “	×	.070308	=	kg. per sq. c-m.
“ “	×	.000703	=	“ “ m-m.
“ cubic in.	×	27.682	=	“ cub. d c-m.
Ins. of mercury	×	.49	=	lbs. per sq. in.
“ “	×	13.596	=	ins. of water.
“ “	×	1.133	=	ft. “
“ “	×	.0333	=	Atmospheres.
“ “	×	2.54	=	c-m. of mercury.
“ “	×	.03445	=	kg. per sq. c-m.
Feet of water	×	.433	=	lbs. “ in.
“ “	×	.02945	=	Atmospheres.
“ “	×	.03044	=	kg. per sq. c-m.
Ins. of water	×	.03608	=	lbs. per sq. in.
“ “	×	.57728	=	oz. “
“ “	×	.07355	=	ins. of mercury.
“ “	×	.002454	=	Atmospheres.
“ “	×	.002537	=	kg. per sq. c-m.
Oz. per sq. in.	×	1.732	=	ins. of water.
“ “	×	.1275	=	“ mercury.
“ “	×	.0625	=	lbs. per sq. in.
“ “	×	.004394	=	kg. per sq. c-m.
Tons “	×	157.49	=	“ “
“ “	×	1.5749	=	“ “ m-m.
Atmospheres	×	14.7	=	lbs. “ in.
“	×	30.	=	ins. } of mercury
“	×	76.2	=	c-m. } at 62° F.
“	×	407.36	=	ins. of water.
“	×	33.947	=	ft. of water.
“	×	1.0335	=	kg. per sq. c-m.
kg. per sq. c-m.	×	29.0267	=	ins. of mercury.
“ “	×	73.727	=	c-m. “

Digitized by Google

USEFUL EQUATIONS.—Continued.

Kg. per sq. c-m.	×	394.139	=	ins. of water.
" "	×	1,000.0	=	c-m. "
" "	×	1.0	=	m. "
" "	×	.9675	=	Atmospheres.
" "	×	14.2232	=	lbs. per sq. in.
" Cub. d c-m.	×	.036124	=	lbs. per cub. in.
" " m m.	×	1422.32	=	lbs. "
" "	×	.635	=	tons "
kg. per sq. metre	×	.205	=	lbs. per sq. ft.
c-m. of mercury	×	.013563	=	kg. per sq. c-m.
" "	×	13.596	=	c-m. of water.
" "	×	.3937	=	ins. of mercury.
" "	×	.01312	=	Atmospheres.
" water	×	.001	=	kg. per sq. c-m.
" "	×	.014205	=	lbs. per sq. in.

VELOCITY AND SPEED.

BRITISH UNITS.	METRIC UNITS.
Feet per second.	Metres per second.
" " minute.	" " minute.
Miles per hour.	" " hour.
Knots " "	Kilometres per hour.
	Knots per hour are also used on European and American Continents.

USEFUL EQUATIONS.

Feet per second	×	.3048	=	metres per second.
" " minute	×	"	=	" " minute.
" " "	×	.011363	=	miles per hour.
" " "	×	.009868	=	knots "
" " "	×	.018287	=	km. "
Miles " hour	×	88.	=	feet per minute.
" " "	×	.8684	=	knots per hour.
" " "	×	1.6093	=	km. "
Knots " "	×	101.333	=	feet per min.
" " "	×	1.151	=	miles per hour.
" " "	×	1.8532	=	km. "

Digitized by Google

USEFUL EQUATIONS.—Continued.

Metres per second	×	3.2808	=	feet per second.
" "	×	196.85	=	" min.
" minute	×	3.2808	=	" "
" "	×	.06	=	km. per hour.
km. per hour	×	.621	=	miles "
" " "	×	.5396	=	knots "

HEAT INTENSITY.

FAHRENHEIT THERMOMETER.

When Barometer at 14.7 lbs. per square inch.
Freezing point of water registers 32°.
Boiling " " " 212°.
180 equal divisions between these points.
Ordinary zero (0°) is 32° below freezing.
Absolute " 461 below ordinary, or 493° below freezing.

CENTIGRADE THERMOMETER.

When Barometer at 14.7 lbs. per square inch.
Freezing point of water registers 0°.
Boiling " " " 100°.
100 equal divisions between these points.
Absolute zero 274° below ordinary.

ORDINARY TEMPERATURES INTO ABSOLUTE.

Fahrenheit——add 461 to ordinary temperature.
Centigrade—— " 274 " " "

Digitized by Google

OUNCES OR FRACTIONS OF POUND AVOIRDUPOIS.

						KILOS.
1	oz. or	$\frac{1}{16}$th	of lb.	=		.02835
2	"	$\frac{1}{8}$th	"	=		.0567
3	"	$\frac{3}{16}$ths	"	=		.0850
4	"	$\frac{1}{4}$th	"	=		.1134
5	"	$\frac{5}{16}$ths	"	=		.1417
6	"	$\frac{3}{8}$ths	"	=		.1701
7	"	$\frac{7}{16}$ths	"	=		.1984
8	"	$\frac{1}{2}$	"	=		.2268
9	"	$\frac{9}{16}$ths	"	=		.2551
10	"	$\frac{5}{8}$ths	"	=		.2835
11	"	$\frac{11}{16}$ths	"	=		.3118
12	"	$\frac{3}{4}$ths	"	=		.3402
13	"	$\frac{13}{16}$ths	"	=		.3685
14	"	$\frac{7}{8}$ths	"	=		.3969
15	"	$\frac{15}{16}$ths	"	=		.42524
16	"	or	1 lb.	=		.4536

KILOGRAMMES AND ENGLISH EQUIVALENTS.

KILOS.				KILOS.			
1	=	2.20462	lbs.	6	=	13.22773	lbs.
2	=	4.40924	"	7	=	15.43235	"
3	=	6.61386	"	8	=	17.63697	"
4	=	8.81848	"	9	=	19.84159	"
5	=	11.02311	"	10	=	22.04621	"

FRACTIONS OF KILOS.

$\frac{1}{16}$th	=	.138	lb.	$\frac{9}{16}$ths	=	1.24	lb.
$\frac{1}{8}$th	=	.2755	"	$\frac{5}{8}$ths	=	1.378	"
$\frac{3}{16}$ths	=	.413	"	$\frac{11}{16}$ths	=	1.516	"
$\frac{1}{4}$th	=	.551	"	$\frac{3}{4}$ths	=	1.653	"
$\frac{5}{16}$ths	=	.689	"	$\frac{13}{16}$ths	=	1.791	"
$\frac{3}{8}$ths	=	.8267	"	$\frac{7}{8}$ths	=	1.929	"
$\frac{7}{16}$ths	=	.9645	"	$\frac{15}{16}$ths	=	2.067	"
$\frac{1}{2}$	=	1.102	"				

Digitized by Google

WEIGHTS AND MEASURES.

AVOIRDUPOIS, OR ORDINARY COMMERCIAL WEIGHT.

UNITED STATES AND BRITISH.

TON.	CWTS.	POUNDS.	OUNCES.
1.	20.	2240.	35840.
0.050	1.0	112.	1792.
	0.0089	1.	16.
		0.0625	1.

1 pound=27.7 cubic inches of distilled water at its maximum density, (39° Fahrenheit.)

LONG MEASURE.

Inches 12=	1 Foot.					
36=	3	1 Yard.				
72=	6	2 =	1 Fathom.			
198=	16.5	5.5 =	2.75=	1 Perch.		
7920=	660	= 220	= 110	= 40	= 1 Furlong.	
63360=	5280	= 1760	= 880	= 320	= 8	= 1 Mile.

SQUARE MEASURE.

Inches 144=	1 Foot.					
1296=	9 =	1 Yard.				
39204=	272.25=	30.25=	1 Perch.			
1568160=	10890	= 1210	= 40	= 1 Rood.		
6272640=	43560	= 4840	= 160	= 4	= 1 Mile.	

An Acre is 69.5700 yards square; or 208.740321 feet square.

A Township	is 6 miles	square =	36 Sections.
A Section	" 1 "	"	= 640 Acres.
1/4 "	" 1/2 "	"	= 160 "
1/16 "	" 1/4 "	"	= 40 "

NAUTICAL MEASURE.

Naut. Mile 1=6086.07 feet,=1.152664 Statute or Land Miles.

" 3= 1 league.

" 60= 20 " =1 Deg.=69.16 Eng. Miles.

Digitized by Google

WEIGHTS AND MEASURES.—Continued.

CUBIC OR SOLID MEASURE.

UNITED STATES AND BRITISH.

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.
A cord of wood = $4' \times 4' \times 8'$ = 128 cubic feet.

A perch of masonry = $16.5' \times 1.5' \times 1'$ = 24.75 cubic feet, but is generally assumed at 25 cubic feet.

DRY MEASURE.

UNITED STATES ONLY.

STRUCK BUSH.	PECKS.	QUARTS.	PINTS.	GALLONS	CUBIC INCH.
1	4	32.	64	8.	2150.
	1	8.	16	2.	537.6
		1.	2	0.25	67.2
		0.5	1	0.125	33.6
		4.	8	1.	268.8

A U. S. gallon of liquid measure = 231 cubic inches.

A heaped bushel = 1¼ struck bushels. The cone in a heaped bushel must be not less than 6 inches high.

A barrel of U. S. hydraulic cement = 300 to 310 lbs., usually, and of genuine Portland cement = 425 lbs.

To reduce U. S. dry measures to British imperial of the same name, divide by 1.032.

The laws of the States of Pennsylvania and Massachusetts which correspond to the similar laws of most of the other States of the United States, provide as follows:

The avoirdupois pound bears to the troy pound the relation of seven thousand to five thousand seven hundred and sixty.

The barrel contains thirty-one and one-half gallons, and the hogshead two barrels.

The dry gallon contains two hundred and eighty-two cubic inches; and the liquid gallon two hundred and thirty-one cubic inches.

The bushel in heap measure contains twenty-one hundred and fifty and forty-two one hundredths cubic inches.

Digitized by Google

COMPARATIVE MEASURES OF WEIGHT.

U. S. SHORT CWT	BR. CWT. 112 POUNDS.	BR. TONS.	KILOGRAMMES.
1	.8928	.04464	45.36
2	1.7856	.08928	90.72
3	2.6786	.13392	136.08
4	3.5714	.17857	181.44
5	4.4641	.22321	226.8
6	5.357	.26786	272.15
7	6.25	.3125	317.51
8	7.1428	.35715	362.87
9	8.0356	.40178	408.23
10	8.9286	.44643	453.59
11	9.822	.49107	498.95
12	10.714	.53572	544.31
13	11.607	.58036	589.67
14	12.5	.625	635.03
15	13.392	.66964	680.38
16	14.286	.7143	725.74
17	15.179	.75895	771.11
18	16.071	.80357	816.46
19	16.965	.84822	861.82
*20	17.857	.89285	907.18
21	18.750	.9375	952.54
22	19.643	.98251	997.9
22.4	20.0	1.0	1016.04

For Metric Quintals Move Point Two to Left.

1 Short Cwt. = 100 Br. lbs.
*1 U. S. Short Ton, = 2000 "
1 " " " = 20 U. S. Short Cwt.

OZ.	LB.	GRAMMES.
1	.0625	28.3495
2	.125	56.699
3	.1875	85.049
4	.25	113.399
5	.3125	141.748
6	.375	170.098
7	.4375	198.447
8	.5	226.797
9	.5625	255.146
10	.625	283.496
11	.6875	311.845
12	.75	340.195
13	.8125	368.544
14	.875	396.894
15	.9375	425.244
16	1.0	453.593

Digitized by Google

UNIT EQUIVALENTS FOR ELECTRIC HEATING PROBLEMS.

1 K. W. hour=	1,000 watt hours. 1.34 horse-power hours. 2,656,400 ft. lbs. 3,600,000 joulés. 3,440 heat units. 366,848 kg. m. 0.229 lb. coal oxidized with perfect efficiency. 3 lbs. water evaporated at at 212° F. 22.9 lbs. water raised from 62° to 212° F. 8 cents at usual rates for electric heating.	1 joulé=	1 watt second. 0.00000278 K. W. hour. 0.102 kg. m. 0.00094 heat unit. 0.73 ft. lb.
		1 ft. lb.=	1.36 joulés. 0.1383 kg. m. 0.000000377 K. W. hour. 0.000291 heat unit. 0.0000005 H. P. hour.
1 H. P. hour=	0.746 K. W. hour. 1,980,000 ft. lbs. 2,580 heat units. 273,740 kg. m. 0.172 lb. coal oxidized with perfect efficiency. 2.25 lbs. water evaporated at 212° F. 17.2 lbs. water raised from 62° to 212° F. 6 cents at usual rates for electric heating.	1 watt=	1 joulé per second. 0.00134 H. P. 0.001 K. W. 3.44 heat units per hour. 0.73 ft. lb. per second. 0.003 lb. of water evaporated per hour. 44.24 ft. lbs. per minute.
		1 watt per sq. in.=	8.26 thermal units per sq. ft. per minute. 120° F. above surrounding air (japanned cast iron surface.) 66° C. above surrounding air (japanned cast iron surface.)
1 K. W.=	1,000 watts. 1.34 H. P. 2,656,400 ft. lbs. per hour. 4,424 ft. lbs. per minute. 73.73 ft. lbs. per second. 3,440 heat units per hour. 573 heat units per minute. 9.55 heat units per second. 0.229 lb. coal oxidized per hour. 3 lbs. water evaporated per hour at 212° F.	1 heat unit=	1.048 watt seconds. 778 ft. lbs. 0.252 caloric (kg. d.) 108 kg. m. 0.000291 K. W. hour. 0.000388 H. P. hour. 0.0000667 lb. coal oxidized. 0.00087 lb. water evaporated at 212° F.
1 H. P.=	746 watts. 0.746 K. W. 33,000 ft. lbs. per minute. 550 ft. lbs. per second. 2,580 heat units per hour. 43 heat units per minute. 0.71 heat unit per second. 0.172 lb. coal oxidized per hour. 2.25 lbs. water evaporated per hour at 212° F.	1 heat unit per sq. ft. per min.=	0.021 watt per sq. in. 0.0174 K. W. 0.0232 H. P.
		1 kg. m.=	7.23 ft. lbs. 0.00000366 H. P. hour. 0.00000272 K. W. hour. 0.0092 heat unit.

Digitized by Google

HEAT UNITS.

The following information regarding Heat Units is from the pen of Dr. Slocum, published in the "American Manufacturer" of February 8th, 1895:

The heating value of any combustible, like its specific gravity, must be based on some unit. There exist at present three different heat units, without any specific name for each, with the exception of the British Heat Unit (B. H. U.), so that they are constantly confused and used without any specification as to which system they belong. Hence it is often difficult or impossible to determine which system is used.

These three systems are: First.—The Centigrade or Continental system, where the Centigrade thermometer is used, here the term applied to the heat unit is the calorie. Second.—The British system, in England, where Fahrenheit is mostly used in scientific research; the term used is the British heat unit (B. H. U.) Third.—The molecule-gram system or the Thomson system. In describing these different systems separately, the same example will be used in each, viz., marsh gas, in order to show clearly the differences numerically in the different systems:

First.—The unit of the French system, the calorie, is the amount of heat required to raise one kilo water one degree Centigrade. Therefore the number of kilos of water that are raised one degree Centigrade by the complete combustion of one kilo of a combustible gives the number of calories or its caloric value, e. g., one kilo marsh gas burned completely to water and carbon dioxid ($C O^2$) will raise 13,244 kilos water one degree Centigrade. As is readily seen, this same number of calories would be obtained if pounds of combustible were

Digitized by Google

used and pounds of water were heated. This system will be termed for convenience, the Centigrade-Kilo system. Abbreviation—C. K.

Second.—The system used in Great Britain is the same as the French, except Fahrenheit is substituted for Centigrade; this decreases the size of one calorie $\frac{4}{9}$ths. Therefore the amount of heat necessary to raise one pound of water one degree Fahrenheit, is one Calorie, e. g., one pound of marsh gas burned completely to water and carbon dioxid ($C\,O^2$) will raise 23,661 pounds of water one degree Fahrenheit. This is the calorie multiplied $\frac{9}{5}$ths. This Calorie is the British heat unit, (B. H. U.) and for convenience will be termed the Fahrenheit-pound system. Abbreviation, F-P.

Third.—The molecular-gram system is based on quite a different method of determination, having no fixed unit of the quantity employed, in fact every combustible employed is taken in different quantities, unless the molecular weight should happen to be the same as the molecular weight of some other substance. A calorie is the amount of heat necessary to raise one gram of water one degree Centigrade; the quantity used is the molecular weight of the substance taken in grams.

All gases, no matter what their composition, have the same sized molecules; therefore, a molecule of any gas takes up one unit of room. In the molecular-gram system, therefore, the amount of substance used is its molecular weight taken in grams, and the caloric value of the substance is expressed in the number of grams of water that that amount of substance will raise one degree Centigrade, e. g., in marsh gas, ($C.\,H^4$) molecular weight 16; then 16 grams of marsh gas burned completely to water and carbon dioxid will raise 211,900 grams of water one degree Centigrade. The caloric value in this case has the advantage of expressing the caloric value of the same volumes of substance when in its gaseous state and conveys quite a different meaning. It is the most useful system for general scientific research, but is apt to be misleading to the general technical world. It will be readily seen that it can be converted into the C-K. system by dividing the total calories given for any substance by its molecular weight, and

Digitized by Google

is further converted into the F-K. system by multiplying this result by $\frac{9}{5}$ths. For convenience we will term this system the the Molecular-gram system. Abbreviation M-G.

Making a comparison of the different values given above, marsh gas has its caloric value expressed as follows in the different systems :

	C-K.	F-P.	M-G.
Marsh gas ($C H^4$)......	13,244	23,839	211,900

These all indicate the same result and are all convertible one into the other; still, when given promiscuously, without any designation as to system, they must certainly be very confusing. The F-P. or the British heat unit is entirely superfluous, and the sooner it is dropped from all classes of heat unit investigations the better ; it is only the C-K. system converted into Fahrenheit, and a division of the number 180 will never make a clear or useful unit for general and accurate work. There are only two temperatures that can be absolutely determined anywhere in the world and be always the same. The first is a mixture of ice and water, which has the same temperature (no matter where) ; hence, it should be zero (0°), as it is on the Centigrade theremometer, being the freezing point of water. The second is the temperature at which water is converted into steam ; the temperature of steam is the same always under an atmospheric pressure of 30 inches of mercury or at sea level ; this can be determined anywhere, making the barometric correction, which is easily done ; therefore, this temperature should be 100°, as it is on the Centigrade scale $\frac{1}{100}$ is a comprehensive division and certainly conveys clearer comprehension of unit than $\frac{1}{180}$, the difference between the freezing and boiling point of water on the Fahrenheit scale.

All three systems are at fault in one respect, which can only be overcome indirectly, as shown below. This difficulty is that the figures given in all systems even with the lowest heating substance are high numbers. The human mind cannot grasp readily comparisons of high figures and be able, at the same time, to use them quickly for comparison. In the tables given below, there has been added another unit for all combustible substances, and a second one for gases. A kilo

Digitized by Google

of pure carbon completely burned to dioxid (CO^2)=8,080 C-K.; this number of calories is taken as a unit or as one heat value, abbreviation H-V., hence: Carbon (C)=1 H V.

Carbon is the best as it is the type of all combustibles, and has a middle value among combustibles. Hence marsh gas, 13,244 C-K., would equal 13,244÷8,080=1.63 H-V.

Marsh gas (CH^4)=1.63 H-V.

That is, one pound of marsh gas equals 1.63 pounds of carbon for heating purposes. The decimals are only carried out two places; if five or over in the third place, one is carried up; if not, it is dropped. This gives a quick, intelligent comparison for general technical use, and, it is believed, will be an aid in the general use of heat unit comparisons, as they are all based on equal weights.

In the case of gases or substances which become gases by solution in other gases, another unit is also used; this unit is used exactly as the specific gravity of gases are compared with air, while all the solids are compared with water. This unit is hydrogen by volume. Hydrogen has the highest heating value of any element or compound and is the lightest. It is unneccessary to take any given volume, but make the comparison direct from the molecular-gram system, as all gases have the same sized molecule. The molecular weight of hydrogen is H2=2, hence, H2=68,435 M-G.; this is taken for the unit. V-C. is the abbreviation for a volume calorie; hence H=1 V-C.

Marsh gas under the M-G. system=211,900.

211,900÷68,435=3.09 V-C.

This makes a quick and intelligent comparison, as the numbers are low and easily grasped in the mind and far easier remembered than the higher numbers.

To estimate the percentage of loss in the practical combustion of any fuel, providing the combustion is complete; the temperature of the products of combustion, where they enter the flue or stack and to which any admixed nitrogen or other neutral gases are added, is multiplied by the quantity (weight) of the products of combustion multiplied by their specific heats (see table below) plus any latent heat that may be in the products of combustion.

Digitized by Google

t°=Temperature.
N=Admixed nitrogen or other gases.
P =Products of combustion.
W=Weight of all gases heated.
s =Specific heat.
L =Latent heat,
Hence: t° [W (Ps + Ns)] + L=Loss in calories.

If the quantity of combustible is known with the admixed air, the nitrogen is taken usually as 77 per cent. by weight. Below the calculation is made from an average analysis of air with impurities, which shows that for every pound of oxygen consumed 3.329 pounds of nitrogen are heated.

Analysis of air containing usual impurities shows:

	By volume.	By weight.
Oxygen	20.94%	23.10 %
Nitrogen	79.02%	76.84 %
Impurities	0.04%	0.06 %

Average weight of 1 liter of air=1.29306 grams, or 1 cubic foot weighs 565 grains.

Air is $\frac{1}{773}$ the weight of water volume for volume.

This article was written before the presence of the element Argon in the atmosphere had been determined. (T. P. R. Co.)

SPECIFIC HEAT.

Calculated under constant pressure and an equal weight of water as unit.

Air	0.2377
Carbon dioxid (CO^2)	0.1843
Nitrogen (N^2)	0.2438
Oxygen (O^2)	0.2175
Water (H^2O) (Gaseous)	0.4805
Water (H^2O) (Liquid)	1.0000 at 0°C
Carbonous Oxid (C O)	0.2425
Sulphurous Oxid (SO^2)	0.1544
Hydrogen	3.4090
Ammonia	0.5356

In the following table are given the weights by volume and heat units of the chief combustibles:

Digitized by Google

HEAT UNIT TABLE.

NAME.	Molecular Symbol.	Atomic Weight.	Molecular Weight.	Products of Combustion.	Specific Gravity Hydrogen=2.	Specific Gravity Air=1.	Weight of 1 Liter in Grams.	Weight of 1 Cu. Ft. in Grains.	Weight of 1 Cu. Ft. in Pounds.	Calories. C-K.	Heat-Value Carbon=1.	Volume-Calorie Hydrogen=1.
Hydrogen	H_2	1	2.	H_2O	2.0000	0.06925	0.08955	39.1263	.00559	34217.5	4.23	1.00
Marsh Gas	CH_4		15.97	H_2O-CO_2	15.974	0.55300	0.71506	312.445	.04464	13244.	1.63	3.09
Carbon Monoxid	CO		27.93	CO_2	27.937	0.96715	1.25058	546.4397	.07806	2441.7	0.302	1.00
Acetylene	C_2H_2		25.94	H_2O-CO_2	25.947	0.89829	1.16148	507.5338	.07255	11923.	1.48	4.53
Aethylene	C_2H_4		27.94	H_2O-CO_2	27.947	0.96749	1.25103	546.6318	.07809	11884.	1.47	4.86
Aethane	C_2H_6		29.94	H_2O-CO_2	29.947	1.03675	1.34058	585.7637	.08368	12347.	1.53	5.41
Propylene	C_3H_6		41.91	H_2O-CO_2	41.921	1.45124	1.87654	819.9506	.11713	11731.	1.45	7.21
Butylene	C_4H_8		55.89	H_2O-CO_2	55.894	1.93488	2.50190	1093.2072	.15617	11619.	1.44	9.51
Allylene	C_3H_4		39.92	H_2O-CO_2	39.921	1.38194	1.78692	780.7961	.11154	11690.	1.45	6.83
Benzole	C_6H_6		77.82	H_2O-CO_2	77.822	2.69463	3.48429	1522.4659	.21749	10102.	1.25	11.51
Naphthalene	$C_{10}H_8$		127.7	H_2O-CO_2	127.722	4.39880	5.68783	2485.322	.35505	9618.7	1.19	17.98
Sulphuretted Hydrogen	H_2S		33.98	SO_2-H_2O	33.981	1.17664	1.52147	664.802	.09497	3488.	0.43	1.73
Carbon Bi-Sulphid	CS_2		75.93	CO_2-SO_2	75.931	2.62580	3.39980	1483.577	.21194	3404.	0.421	3.79
Water Gas	* See analysis below.				15.562	0.53883	0.69678	304.438	0.04349	4839.7	0.5989	0.936
Coal Gas	* See analysis below.				11.332	0.39236	0.50739	186.620	0.02666	13817.	1.710	1.924
Ammonia	NH_3		17.01	H_2O-N_2	17.010	0.58901	0.76163	332.790	.47543	5332.	0.659	1.33
Air					14.444	1.00000	1.29306	565.000	.08071			
Nitrogen	N_2	14.01	28.02		28.021	0.97026	1.25461	548.197	.07831			
Oxygen	O_2	15.96	31.92		31.920	1.10531	1.42923	624.500	.08921			
Carbon Dioxid	CO_2		43.89		43.892	1.51980	1.96519	858.687	.12267			
Carbon from Wood	C_2	11.97	23.94	CO_2						8080.	1.000	
Anthracite—Penna				CO_2-H_2O						7844.4	0.971	
Bituminus Coal				CO_2-H_2O						8391.7	1.038	
Cannel Coal				CO_2-H_2O						6365.5	0.788	
Furnace Coke				CO_2-H_2O						7019.4	0.868	
Gas House Coke				CO_2-H_2O						7000.	0.866	
Coal Tar				CO_2-H_2O						8667.	1.073	
Crude Petroleum				CO_2-H_2O						11094.1	1.373	

* Note.

	Water Gas. (Uncarburetted.)	Coal Gas.
Hydrogen	49.2 %	50.28 %
Marsh gas	0.3 %	36.95 %
Illuminants	Trace.	6.34 %
Carbon monoxid	43.8 %	4.37%
Carbon dioxid	2.7 %	None.
Nitrogen	4.0 %	Trace.

Digitized by Google

USEFUL INFORMATION.

STEAM.

A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic *foot* of steam (approximately.

Steam at atmospheric pressure flows into a *Vacuum* at the rate of about 1,550 feet per second, and into the *Atmosphere* at the rate of 650 feet per second.

The specific gravity of steam (at atmospheric pressure) is .411 that of air at 34° Fahrenheit, and .0006 that of water at same temperature.

27,222 cubic feet of steam, at atmospheric pressure, weigh 1 pound: 13,817 cubic feet of air weigh 1 pound.

Boilers require for each *nominal* horse power about 1 cubic foot of feed water per hour.

Locomotives average a consumption of 3000 gallons of water per 100 miles run.

The best designed boilers, well set, with good draft and skillful firing, will evaporate from 7 to 10 lbs. of water per pound of best quality coal. The average result is from 25 to 60 per cent. below this.

In calculating horse-power of tubular or flue boilers, consider 15 square feet of heating surface equivalent to one *nominal* horse power.

One square foot of grate will consume on an average 12 lbs., of coal per hour.

Steam engines, in economy, vary from 20 to 60 lbs. of feed water and from 1½ to 7 lbs. of coal per hour per indicated horse power.

Condensing engines require from 20 to 30 gallons of water to condense the steam represented by every gallon of water evaporated—approximately say from 1 to 1½ gallons per minute per indicated horse power.

Digitized by Google

Ratio of Vacuum to Temperature (Fahrenheit) of Feed Water.

00 inches,	Vacuum		212°
11	"	"	190°
18	"	"	170°
22½	"	"	150°
*25	"	"	135°
27½	"	"	112°
28½	"	"	92°
29	"	"	72°
29½	"	"	52°

* Usually considered the standard point of efficiency—condenser and air pump being well proportioned.

USEFUL INFORMATION.

WATER.

Doubling the diameter of a pipe increases its capacity four times. Friction of liquids in pipes increases as the square of the velocity.

The mean pressure of the atmosphere is usually estimated at 14.7 lbs. per square inch, so that with a perfect vacuum it will sustain a column of mercury 29.9 inches or a column of water 33.9 feet high.

To find the pressure in pounds per square inch of a column of water. Multiply the height of the column in feet by .434. Approximately, we say that every foot of elevation is equal to ½ lb. pressure per square inch; this allows for ordinary friction.

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the standard of speed.) Divide the number of gallons by 4; then extract the square root, and the product will be the diameter in inches of the pump cylinder.

To find the quantity of water elevated in one minute running at 100 feet of piston speed per minute. Square the diameter of the water cylinder in inches and multiply by 4. Example: Capacity of a 5-inch cylinder is desired. The square of the diameter (5 inch) is 25, which multiplied by 4 gives 100, the number of gallons per minute (approximately.)

Digitized by Google

To find the horse power necessary to elevate water to a given height. Multiply the total weight of the water to be elevated in one minute in lbs. by the height in feet, and divide the product by 33,000 (an allowance of 25 per cent. should be added for water friction, and a further allowance of 25 per cent. for loss in steam cylinder.)

The area of the steam piston, multiplied by the steam pressure, gives the total amount of pressure that can be exerted. *The area of the water piston*, multiplied by the pressure of water per square inch, gives the resistance. *A margin* must be made between the *power* and the *resistance* to *move* the pistons at the required speed—say from 20 to 40 per cent., according to speed and other conditions.

To find the capacity of a pumping cylinder in gallons. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches. Divide this number 231 (which is the cubical contents of a U. S. gallon in inches), and product is the capacity in gallons.

WEIGHT AND CAPACITY OF DIFFERENT STANDARD GALLONS OF WATER.

	Cubic Inches in a Gallon.	Weight of a Gallon in Pounds.	Gallons in a Cubic Foot.
Imperial or English	277.274	10.00	6.232102
United States....	231.	8.33111	7.480519
New York	221.819	8.00	7.901285

Weight of a cubic foot of water, English standard, 62,321 lbs. avoirdupois.

Weight of crude or refined petroleum, 6½ lbs. per U. S. gallon; 42 gallons to the barrel.

A "miner's" inch of water is approximately equal to a supply of 12 U. S. gallons per minute.

WEIGHT AND COMPARATIVE FUEL VALUE OF WOOD.

1 cord air-dried Hickory or Hard Maple weighs about 4500 lbs., and is equal to about 2000 lbs. coal.

1 cord air-dried White Oak weighs about 3850 lbs., and is equal to about 1715 lbs. coal.

Digitized by Google

1 cord air-dried Beech, Red or Black Oak weighs about 3250 lbs., and is equal to about 1450 lbs. coal.

1 cord air-dried Poplar (whitewood), Chestnut or Elm weighs about 2350 lbs., and is equal to about 1050 lbs. coal.

1 cord air-dried average Pine weighs about 2000 lbs., and is equal to about 925 lbs. coal.

From the above it is safe to assume that 2¼ lbs. of dry wood is equal to 1 lb. average quality of soft coal, and that the full value of the same *weight* of different woods is very nearly the same—that is, a pound of hickory is worth no more for fuel than a pound of pine, assuming both to be dry. It is important that the wood be dry, as each 10 per cent. of water or moisture in wood will detract about 12 per cent. from its value as fuel.

DUTY OF STEAM ENGINES.

The following are comparative figures showing the economy of high-grade steam engines in actual practice:

TYPE OF ENGINE.	Temperature of Feed Water.	Pounds of Water Evaporated per pound of Cumberland Coal.	Pounds of Steam per I. H. P. used per hour.	Pounds of Cumberland Coal used per I. H. P. per hour.	Cost of I. H. P. per hour supposing Coal at $6.00 per ton.
Non-Condensing ...	210°	10.5	29.	2.75	$0.0073
Condensing........	100°	9.4	20.	2.12	0.0056
Compound Jacketed.	100°	9.4	17.	1.81	0.0045

The effect of a good condenser and air pump should be to make available about 10 lbs. more mean effective pressure, with the same terminal pressure; or to give the same mean effective pressure, with a correspondingly less terminal pressure. When the load on the engine requires 20 lbs. M. E. P., the condenser does half the work; at 30 lbs., one-third of the work; at 40 lbs., one-fourth, and so on. It is safe to assume that practically the condenser will save from one-fourth to one-third of the fuel, and it can be applied to any engine, cut-of, or throttling, where a sufficient supply of water is available.

Digitized by Google

THE HORSE-POWER OF BOILERS.

When an order is given for a boiler of a stated number of "nominal horse-power" it is understood (in the absence of of any agreement to the contrary) that a "horse-power" means the evaporation of 30 pounds of water per hour, under the conditions stated above.

In computing the horse-power of a boiler by the Centennial rule, or by any other rule, the first problem is to find the heating surface of the proposed boiler, which consists of all those parts of the shell, heads and tubes, which are exposed to the direct action of the fire or of the hot gases that come from it. Considering these parts in detail:

The part of the *shell* which is exposed to the fire, extends from the back head to the rear surface of the front wall of the setting; and it is limited at the top by the side walls, where they extend inward and touch the boiler. To obtain this area with precision, one should know the exact length of the shell exposed to the fire, and also the height of the side walls of the furnace; but in practice it is usually assumed that the part of the shell exposed to the fire is equal to one-half of the area of the entire shell (omitting the dry-sheet, of course, in case there is one.) This simplifies the calculation very much, and yet the results correspond quite closely to the actual facts. The *front head* of the boiler is of little or no value as a heating surface, because, if the boiler is well designed, the temperature in the uptake does not greatly exceed the temperature of the boiler itself, and hence there cannot be any considerable absorption of heat through the front head. This head should therefore be entirely omitted in the calculation. The *back head* is more directly exposed to the heat of the furnace, and allowance is sometimes made for such heating surface as it contains. In general practice no allowance is made for the

Digitized by Google

back head, however, because the only part of its surface which is available, in any case, consists in the small segments which lie between the tubes, together with a narrow strip around the flange and just under the back arch. While there might be some heating value to these parts when the boiler is new, it is not considered that they are worth taking into account after it has been used for a time, because scale is likely to form upon them; and even though the scale were not heavy enough to produce over-heating, and consequent injury to the boiler, it might still be quite sufficient to destroy the efficiency of the head, when considered as a heating surface. The *tubes* are of a great importance in computing the heating surface, because their combined area is very large. Some engineers base the calculated heating surface upon the internal diameter of the tubes, while others use the external diameter, and still others the average of the two. General practice has been to take the *external* diameter.

This point being settled, the next step is to find the area of the tube, by multiplying its outside circumference by its length—the circumference being found by multiplying the outside diameter by 3.1416. (The diameter of the tube is usually given in *inches;* so that if the surface is required in *square feet*, it is necessary to divide the given diameter (or circumference) of the tube by 12, so that it may be expressed as a fraction of of a foot.) The area of one tube being thus found, it is multiplied by the *number* of tubes, and thus finds the united surface of all of them. This, when added to the heating surface afforded by the shell, gives the entire surface upon which the rated horse-power of the boiler is to be based.

Rule for Finding the actual Horse Power :—First find the heating surface (in square feet) as described above. Multiply this by 2½, which will give the number of pounds of steam that the boiler can produce per hour. The evaporation thus found is then to be divided by the weight of steam required by the engine that is to be used, per horse-power per hour, and the quotient is the actual horse-power that may reasonably be expected when the proposed boiler and engine are run together under favorable conditions.

Digitized by Google

TABLE OF CENTIGRADE AND FAHRENHEIT DEGREES.

Deg. C.	Deg. F.	Deg. C.	Deg. F.	Deg. C.	Deg. F.	Deg. C.	Deg. F.	Deg. C.	Deg. F.
0	32.	21	69.8	41	105.8	61	141.8	81	177.8
1	33.8	22	71.6	42	107.6	62	143.6	82	179.6
2	35.6	23	73.4	43	109.4	63	145.4	83	181.4
3	37.4	24	75.2	44	111.2	64	147.2	84	183.2
4	39.2	25	77.	45	113.	65	149.	85	185.
5	41.	26	78.8	46	114.8	66	150.8	86	186.8
6	42.8	27	80.6	47	116.6	67	152.6	87	188.6
7	44.6	28	82.4	48	118.4	68	154.4	88	190.4
8	46.4	29	84.2	49	120.2	69	156.2	89	192.2
9	48.2	30	86.	50	122.	70	158.	90	194.
10	50.	31	87.8	51	123.8	71	159.8	91	195.8
11	51.8	32	89.6	52	125.6	72	161.6	92	197.6
12	53.6	33	91.4	53	127.4	73	163.4	93	199.4
13	55.4	34	93.2	54	129.2	74	165.2	94	201.2
14	57.2	35	95.	55	131.	75	167.	95	203.
15	59.	36	96.8	56	132.8	76	168.8	96	204.8
16	60.8	37	98.6	57	134.6	77	170.6	97	206.6
17	62.6	38	100.4	58	136.4	78	172.4	98	208.4
18	64.4	39	102.2	59	138.2	79	174.2	99	210.2
19	66.2	40	104.	60	140.	80	176.	100	212.
20	68.								

RELATIONS OF THERMOMETRIC SCALES.

9 Fahrenheit degrees = 5 Centigrade degrees = 4 Reaumur degrees.
1 degree Fahrenheit = 0.5556 degree Centigrade.
1 degree Centigrade = 1.8 degree Fahrenheit.

To Convert

Fahrenheit to Centigrade, subtract 32, multiply by 5, and divide by 9.*
" " Reaumur, " 32. " " 4, " " " 9.*
Centigrade to Fahrenheit, multiply by 9, divide by 5, and add 32.*
" " Reaumur, " " 4, " " 5.
Reaumur to Fahrenheit, " " 9, " " 4, and add 32.*
" " Centigrade, " " 5, " " 4.

Example.—212° Fahrenheit to Centigrade, 212 − 32 = 180 × 5 ÷ 9 = 100° Centigrade.

*** If the temperature is below freezing, where above formulae read "add 32" becomes subtract *from* 32, and where formulae read "subtract 32," becomes substract *from* 32**

Digitized by Google

COMPARATIVE FUEL VALUE OF COAL, OIL AND GAS.

1 pound of coal will evaporate 10 pounds of water at 212 degrees atmospheric pressure.

1 pound of oil will evaporate 16 pounds of water at 212 degrees atmospheric pressure.

1 gallon crude lima oil 60° F., weighs 6.8945 lbs.

1 pound of natural gas will evaporate 20 pounds of water at 212 degrees atmospheric pressure.

1 pound of coal will equal 11.225 cubic feet natural gas.

2000 pounds (1 ton) will equal 22,450 cubic feet natural gas.

1 pound of oil will equal 18 cubic feet natural gas.

1 barrel (42 gallons) will equal 5,310 cubic feet natural gas.

1.125 cubic feet natural gas will evaporate 1 pound of water.

1 cubic foot natural gas will equal 860 B. H. U.

1000 cubic feet natural gas will equal 860,000 B. H. U.

1 ton of coal will equal 19,307,000 B. H. U.

1 barrel of oil will equal 4,566,600 B. H. U.

At an evaporation of 5½ lbs. water to one pound coal feed water at 60° F., 5.46 lbs. of coal will develop one horse-power and 3.03 barrels (42 gallons each) of oil equals one ton of coal for steam making purposes under boilers.

1 LB. BITUMINOUS COAL OXIDIZED WITH PERFECT EFFICIENCY=

15,000 heat units.
0.98 lb. anthracite coal oxidized.
2.1 lbs. dry wood oxidized.
15 cu. ft. illuminating gas.
4.37 K. W. hours (theoretical value.)
5.81 H. P. hours (theoretical value.)
11,590,000 ft. lbs. (theoretical value.)
13.1 lbs. of water evaporated at 212° F.

1 LB. WATER EVAPORATED AT 212° F.=

0.33 K. W. hour.	124,200 kg. m.
0.44 H. P. hour.	1,219,000 joulés.
1 148 heat units.	887,800 ft. lbs.

0.076 lb. of coal oxidized.

Digitized by Google

F. W. CLARKE'S LIST OF THE ATOMIC WEIGHTS OF THE 74 KNOWN AND RECOGNIZED ELEMENTS.

JANUARY 3RD, 1896.

Chemical Symbol.		Reckoning Hydrogen as One.	Reckoning Oxygen as Sixteen.
Al	**Aluminum**	**26.91**	**27.11**
Sb	Antimony	119.52	120.43
A	Argon	?	?
As	Arsenic	74.52	75.09
Ba	Barium	136.40	137.43
Bi	Bismuth	206.54	208.11
B	Boron	10.86	10.95
Br	Bromine	79.34	79.95
Cd	Cadmium	111.08	111.93
Cs	Caesium	131.89	132.89
Ca	Calcium	39.78	40.08
C	Carbon	11.92	12.01
Ce	Cerium	139.1	140.2
Cl	Chlorine	35.18	35.45
Cr	Chromium	51.74	52.14
Co	Cobalt	58.49	58.93
	Columbium	93.3	94.0
Cu	Copper	63.12	63.60
Er	Erbium	165.0	166.3
F	Fluorine	18.89	19.3
	Gadolinium	154.9	156.1
Ga	Gallium	68.5	69.0
Ge.	Germaninm	71.75	72.3
Gl or Be	Glucinum	9.01	9.08
Au	Gold	195.74	197.24
He.	Helium	?	?
H	Hydrogen	1.00	1.008
In	Indium	112.8	113.7
I	Iodine	125.89	126.85
Ir	Iridium	191.66	193.12
Fe	Iron	55.60	56.02
La	Lanthanum	137.6	138.6
Pb	Lead	205.36	206.92
Li	Lithium	6.97	7.03

Digitized by Google

F. W. CLARKE'S LIST OF THE ATOMIC WEIGHTS.—Continued.

Chemical Symbol.		Reckoning Hydrogen as One.	Reckoning Oxygen as Sixteen.
Mg....	Magnesium................	24.11	24.29
Mn.....	Manganese	54.57	54.99
Hg.....	Mercury.................	198.5	200.00
Mo. ...	Molybdenum..............	95.26	95.98
	Neodymium................	139.4	140.5
Ni. ...	Nickel....................	58.24	58.69
N......	Nitrogen	13.94	14.04
Os.....	Osmium..................	189.55	190.99
O......	Oxygen	15.879	16.00
Pd.....	Palladium	105.56	106.36
P......	Phosphorus...............	30.79	31.02
Pt.....	Platinum	193.41	194.89
K......	Potassium	38.82	39.11
	Praseodymium	142.4	143.5
Rh.....	Rhodium.................	102.23	103.01
Rb....	Rubidium	84.78	85.43
Ru.....	Ruthenium	100.91	101.68
Sm.....	Samarium	148.9	150.0
Sc......	Scandium	43.7	44.0
Si......	Silicon	28.18	28.40
Se.....	Selenium	78.4	79.0
Ag.....	Silver....................	107.11	107.92
Na.....	Sodium...................	22.88	23.05
Sr.....	Strontium	86.95	87.61
S......	Sulphur	31.83	32.07
Ta.....	Tantalum.................	181.2	182.6
Te.....	Tellurium................	126.1 ?	127.0 ?
Tr.....	Terbium.	158.8	160.0
Tl......	Thallium	202.60	204.15
Th.....	Thorium..................	230.87	232.63
Tm	Thulium	169.4	170.7
Sn.....	Tin.......................	118.15	119.05
Ti	Titanium..................	47.79	48.15
W.. ...	Tungsten.................	183.44	184.84
U......	Uranium	237.77	239.59
V......	Vanadium	50.99	51.38
Yb.....	Ytterbium	171.7	173.0
Y......	Yttrium	88.28	88.95
Zn.....	Zinc	64.91	65.41
Zr. ...	Zirconium	89.9	90.6

Digitized by Google

TABLES OF THE WORLD'S MONEY UNITS.

Quoted from Monetary Systems of the World by M. L. Muhleman, Deputy Assistant Treasurer of the United States.

Weights are given in grammes, values in United States coin, fineness in thousandths.
The value of silver coins is based upon the coining value of an ounce of silver in the United States, $1.2929.
The Gramme = 15.432 grains.
Countries with § have now (1896) a depreciated paper basis; gold being at a premium.

SINGLE-GOLD STANDARD COUNTRIES.

Country.	Unit.	Value.	Weight.	Fineness.	Subsidiary Silver Coin. Principal Coin.	Weight.	Fineness.	Equivalent at Coining Rate.
Great Britain	Pound	$4.86⅔	7.988	.916⅔	Shilling	5.655	.925	$0.217
Germany	Mark	.238	.398	.900	Mark	5.555	.900	.208
Sweden }								
Norway }	Krone	.268	.448	.900	Krone	7.5	.800	.249
Denmark }								
Austria-Hungary	Krone	.203	.33⅞	.900	Krone	5.	.835	.174
Roumania	Ley	.193	.3226	.900	Ley	5.	.835	.174
Turkey §	Piaster	.044	.072	.916⅔	5-piasters	6.014	.830	.207
Portugal §	Milreis	1.08	1.774	.916⅔	Testoon	2.5	.916⅔	.095
Brazil §	Milreis	.546	.8965	.917	Milreis	12.75	.917	.486
Canada	Dollar	1.00	No gold	coins	Half-dollar	11.62	.925	.446
Newfoundland	Dollar	1.014	1.664	.916⅔	Half-dollar	11.782	.925	.448
Egypt	Pound	4.943	8.5	.875	5-piasters	7.	.833⅓	.243
Chile	Peso	.549	.365	.916⅔	Peso	20.	.835	.694

Australasia, Cape Colony, the British West Indies have the British standard, and in Canada the pound sterling is also a legal tender.

Digitized by Google

SINGLE-SILVER STANDARD COUNTRIES.

Country.	Unit.	Equivalent at Coining Rate.	Weight.	Fineness.	Subsidiary Pieces = to Unit.		Gold Piece = to Unit.		
					Weight.	Fineness.	Weight.	Fineness.	Value.
Russia §	Rouble	$0.748	19.996	.900	17.99	.500	1.29	.900	$0.772
Mexico	Peso	1.016	27.073	.9027	27.073	.9027	1.692	.875	.984
Central America	Peso	.935	25.	.900	25.	.835	1.613	.900	.965
Colombia §	Peso	.935	25.	.900	25.	.835	1.613	.900	.965
Bolivia	Boliviano	.935	25.	.900	25.	.900	1.613	.900	.965
Peru	Sol	.935	25.	.900	25.	.900	1.613	.900	.965
Ecuador §	Sucre	.935	25.	.900	25.	.900	1.613	.900	.965
India	Rupee	.444	11.664	.916⅔	11.664	.916⅔	11.664*	.916⅔	7.109
Japan	Yen	1.008	26.956	.900	25.	.800	1.667	.900	.997
China	Tael†	1.364	36.56	......	....	......	No coins.		
Hong-Kong and Straits	Dollar	1.008	26.956	.900	25.	.800	No coins.		
Cochin-China	Piaster	1.018	27.215	.900	27.215	.900	No coins.		

* Mohur = to 15 rupees. † Shanghai tael. The new dollar coinage has not yet been rated.

Digitized by Google

DOUBLE STANDARD COUNTRIES.

Country.		Unit.	Value.	Gold Unit.		Silver Unit.		Subsidiary Coin.		
				Weight.	Fineness.	Weight.	Fineness.	Weight.	Fineness.	Value.
United States		Dollar	$1.00	1.672	.900	26.729	.900	25.	.900	$0.935
Haiti		Gourde	.965	1.613	.900	25.	.900	25.	.835	.870
Uruguay§		Peso	1.034	1.697	.917	25.	.900	25.	.900	.935
Argentine Republic §		Peso	.965	1.613	.900	25.	.900	25.	.900	.935
Venezuela		Bolivar	.193	.3226	.900	5.	.900	5.	.835	.174
France	The Latin Union	Franc								
Belgium	The Latin Union	Franc								
Italy§	The Latin Union	Lira	.193	.3226	.900	5.	.900	5.	.835	.174
Switzerland	The Latin Union	Franc								
Greece§	The Latin Union	Drachma								
Spain§		Peseta	.193	.3226	.900	5.	.900	5.	.835	.174
Servia		Dinar	.193	.3226	.900	5.	.900	5.	.835	.174
Bulgaria		Lew	.193	.3226	.900	5.	.900	5.	.835	.174
Netherlands		Florin	.402	.672	.900	10.	.945	3.57	.640	.095
Algeria		Franc	.193	.3226	.900	5.	.900	5.	.835	.174
Tunis		Franc	.193	.3226	.900	5.	.900	5.	.835	.174
Java, etc.		Florin	.402	.672	.900	10.	.900	3.57	.640	.095
Philippine Islands		Peso	.983	1.691	.875	25.96	.945	25.96	.900	.971
Hawaii		Dollar.	1.00	1.672	.900	26.729	.900	25.	.900	.935

Digitized by Google

RATES OF POSTAGE.—(United States.)

Postal Cards.—1 cent each, go without further charge to all parts of the United States and Canada. Cards for foreign countries (within the Postal Union), 2 cents each. Postal cards are unmailable with any writing or printing on the address side, except the direction, or with anything pasted upon or attached thereto.

Letters.—To all parts of the United States, Canada and Mexico, 2 cents each ounce or fraction thereof.

Local, or "Drop" Letters,—That is, for the city or town where deposited, 2 cents where the carrier system is adopted, and 1 cent where there is no carrier system.

First Class:—Letters and written matter, whether sealed or unsealed, and all other matter sealed, nailed, sewed, or fastened in any manner so that it cannot be easily examined, 2 cents for each ounce or fraction thereof.

Second Class:—Only for publishers and news agents, 1 cent per pound.

Newspapers and Periodicals (regular publications) can be mailed by the public at the rate of 1 cent for each 4 ounces or fraction thereof.

Third Class:—Printed matter, in unsealed wrappers only (all matter enclosed in notched envelopes must pay letter rates), 1 cent for each 2 ounces or fraction thereof, which must be fully prepaid. This includes books, circulars, etc.

Fourth Class:—All mailable matter not included in the three preceding classes which is so prepared for mailing as to be easily withdrawn from the wrapper and examined, 1 cent per ounce or fraction thereof. Limit of weight, 4 pounds. Full prepayment compulsory.

MONEY ORDERS.

On and after July 1, 1894, the fees for the issue of Domestic Money orders will be as follows:

For orders not exceeding $2.50,	3 cents.
For orders exceeding $ 2.50 and not exceeding $ 5.00,	5 "
For orders exceeding $ 5.00 and not exceeding $ 10 00,	8 "
For orders exceeding $10.00 and not exceeding $ 20.00,	10 "
For orders exceeding $20 00 and not exceeding $ 30.00,	12 "
For orders exceeding $30.00 and not exceeding $ 40.00,	15 "
For orders exceeding $40.00 and not exceeding $ 50.00,	18 "
For orders exceeding $50 00 and not exceeding $ 60 00,	20 "
For orders exceeding $60.00 and not exceeding $ 75.00,	25 "
For orders exceeding $75.00 and not exceeding $100.00,	30 "

REGISTRATION.

All kinds of postal matter, except second-class matter, can be registered at the rate of eight cents for each package in addition to the regular rates of postage, to be fully prepaid by stamps. Each package must bear the name and address of the sender, and a receipt will be returned from the person to whom addressed. Mail matter can be registered at all post-offices in the United States.

The Post Office Department or its revenue is not by law liable for the loss of any registered mail matter.

FOREIGN POSTAGE.

The rates for letters are for the half ounce or fraction thereof and those of newspapers for two ounces or fraction thereof.

To Great Britain and Ireland, France, Spain, all parts of Germany, including Austria, Denmark, Switzerland, Italy, Russia, Norway, Sweden, Turkey (European and Asiatic), Egypt, Australia (all parts), letters, 5 cents; newspapers, 1 cents.

China or Japan:—Letters via San Francisco, Brindisi or England, 5 cents; newspapers, 1 cent for two ounces.

British India, Italian Mail:—Letters, 5 cents; newspapers, 1 cent two ounces.

Digitized by Google

VALUES OF FOREIGN COINS.

COPY OF
Department Circular No. 51,
1896.

UNITED STATES TREASURY DEPARTMENT,

BUREAU OF THE MINT.

Hon. JOHN G. CARLISLE, Secretary of the Treasury. Washington, D. C., April 1, 1896.

SIR:—In pursuance of the provisions of section 25 of the act of August 28, 1894, I present in the following table an estimate of the values of the standard coins of the nations of the world:

COUNTRY.	STANDARD.	MONETARY UNIT.	Value in terms of U. S. gold dollars.	COINS.
Argentine Republic	Gold and silver	Peso	$0.965	Gold: argentine ($4.824) and ½ argentine. Silver: peso and divisions.
Austria-Hungary	Gold	Crown	.203	Gold: former system—4 florins ($1.929), 8 florins, ($3.858), ducat ($2.287) and 4 ducats ($9.149.) Silver: 1 and 2 florins. Gold: present system—20 crowns ($4.052); 10 crowns ($2.026.)
Belgium	Gold and silver	Franc	.193	Gold: 10 and 20 francs. Silver: 5 francs.
Bolivia	Silver	Boliviano	.493	Silver: boliviano and divisions.
Brazil	Gold	Milreis	.546	Gold: 5, 10 and 20 milreis. Silver: ½, 1 and 2 milreis.
British Possessions N. A. (except Newfoundland.)	Gold	Dollar	1.000	
Central Amer. States—Costa Rica, Guatamala, Honduras, Nicaragua, Salvador	Silver	Peso	.493	Silver: peso and divisions.

Digitized by Google

VALUE OF FOREIGN COINS.—CONTINUED.

COUNTRY.	STANDARD.	MONETARY UNIT.	Value in terms of U. S gold dollar†.	COINS.
Chile	Gold and silver	Peso	.912	Gold: escudo ($1.824), doubloon ($4.561,) and condor ($9.123). Silver: peso and divisions.
China	Silver	Tael: Shanghai	.729	
		Tael: Haikwan (Customs)	.812	
		Tael: Tientsin	.773	
		Tael: Chefoo	.763	
Colombia	Silver	Peso	.493	Gold: condor ($9.647) and double-condor. Silver: peso.
Cuba	Gold and silver	Peso	.926	Gold: doubloon ($5.017.) Silver: peso.
Denmark	Gold	Crown	.268	Gold: 10 and 20 crowns.
Ecuador	Silver	Sucre	.493	Gold: condor ($9.647) and double condor. Silver: sucre and divisions.
Egypt	Gold	Pound (100 piasters)	4.943	Gold: pound (100 piasters), 5, 10, 20 and 50 piasters. Silver: 1, 2, 5, 10 and 20 piasters.
Finland	Gold	Mark	.193	Gold: 20 marks ($3.859), 10 marks ($1.93.)
France	Gold and silver	Franc	.193	Gold: 5, 10, 20, 50 and 100 francs. Silver: 5 francs.
German Empire	Gold	Mark	.238	Gold: 5, 10 and 20 marks.
Great Britain	Gold	Pound sterling	4.866½	Gold: sovereign (pound sterling) and ½ sovereign.
Greece	Gold and silver	Drachma	.193	Gold: 5, 10, 20, 50 and 100 drachmas. Silver; 5 drachmas.
Haiti	Gold and silver	Gourde	.965	Silver: gourde.
India	Silver	Rupee	.234	Gold: mohur ($7.105.) Silver: rupee and divisions.
Italy	Gold and silver	Lira	.193	Gold: 5, 10, 20, 50 and 100 lire. Silver: 5 lire.
Japan	Gold and silver*	Yen: Gold	.997	Gold: 1, 2, 5, 10 and 20 yen.
		Yen: Silver	.532	Silver: yen.

* Gold is the nominal standard. Silver the actual standard.
The value of units of silver-standard countries varies with the price of silver.

Digitized by Google

VALUE OF FOREIGN COINS.—CONTINUED.

COUNTRY.	STANDARD.	MONETARY UNIT.	Value in terms of U. S. Gold dollars.	COINS.
Liberia	Gold	Dollar	1.000	
Mexico	Silver	Dollar	.536	Gold: dollar ($0.983), 2½, 5, 10 and 20 dollars. Silver: dollar (or peso) and division.
Netherlands	Gold and silver	Florin	.402	Gold: 10 florins. Silver: ½, 1 and 2½ florins
Newfoundland	Gold	Dollar	1.014	Gold: 2 dollars ($2.027.)
Norway	Gold	Crown	.268	Gold: 10 and 20 crowns.
Persia	Silver	Kran	.091	Gold: ½, 1 and 2 tomans ($3.409.) Silver: ¼, ½, 1, 2 and 5 krans.
Peru	Silver	Sol	.493	Silver: sol and divisions.
Portugal	Gold	Milreis	1.080	Gold: 1, 2, 5 and 10 milreis.
Russia	Silver‡	Ruble — Gold	.772	Gold; imperial ($7.718), and ½ imperial † ($3.86.)
		Ruble — Silver	.395	Silver: ¼, ½ and 1 ruble.
Spain	Gold and silver	Peseta	.193	Gold: 25 pesetas. Silver: 5 pesetas.
Sweden	Gold	Crown	.268	Gold: 10 and 20 crowns.
Switzerland	Gold and silver	Franc	.193	Gold: 5, 10, 20, 50 and 100 francs. Silver: 5 francs.
Tripoli	Silver	Mahbub of 20 piasters.	.445	
Turkey	Gold	Piaster	.044	Gold: 25, 50 100, 250 and 500 piasters.
Venezuela	Gold and silver	Bolivar	.193	Gold: 5, 10, 20, 50 and 100 bolivars. Silver: 5 bolivars.

† Ccined since January 1st, 1886. Old half-imperial=$3.986.
‡ Silver the nominal standard. Paper the actual currency, the depreciation of which is measured by the gold standard.

Respectfully, R. E. PRESTON, Director of the Mint.

TREASURY DEPARTMENT,
OFFICE OF THE SECRETARY.

Washington, D. C., April 1, 1896.

The foregoing estimate by the Director of the Mint, of values of foreign coins, I hereby proclaim to be the values of such coins in the terms of the money of account of the United States, to be followed in estimating the value of all foreign merchandise exported to the United States on or after April 1, 1896, expressed in any such metallic currencies.

J. G. CARLISLE, Secretary of the Treasury of the United States

Digitized by Google

DESCRIPTIVE TABLE OF UNITED STATES GOLD COINS IN USE DECEMBER, 1896.

DENOMINATION.	WEIGHT.	FINENESS.	DIAMETER.	THICKNESS.
Double-eagle,	516 grains.	.900	1.35 in.	.077 in.
Eagle,	258 "	.900	1.05 "	.060 "
Half-eagle,	129 "	.900	.85 "	.046 "
Quarter-eagle,	64½ "	.900	.75 "	.034 "

Deduced from the above table, the value of gold of standard fineness (.900) is \$18.60½, and if *fine* or pure, \$20.67$\frac{2}{10}$ per ounce.

The coinage of gold dollars and three-dollar pieces was suspended by the act of September 26th, 1890.

According to the law of January 18, 1837, the weight of the silver dollar was fixed at 412½ grains, and the fineness at 900-thousandths; leaving the weight of pure silver 371¼ grains. This changed the ratio to 15.988 (or nearly 16) to 1, and the coining value of silver at 1.29$\frac{29}{100}$.

The Mint Act of 1873 discontinued the coinage of the dollars by omitting it from the list of authorized coins.

In 1878 (February 28th), Congress passed, over the veto of President Hayes, a law again authorizing its coinage, but in a limited amount only; not less than \$2,000,000 nor more than \$4,000,000 worth of silver was to be purchased monthly and coined into the dollars of 1837; the coin was made a legal tender for all debts, public and private, unless otherwise stipulated—excepting for the redemption of gold certificates of the Government. The seigniorage accrued to the Treasury.

Under the Mint Act of 1873, the change to the present (December, 1896) subsidiary **silver coinage** took place. The description of the pieces follows:

DENOMINATION.	W'GHT IN GRAINS.	PURE SILVER.	DIAMETER.	THICKNESS.
Half-dollar,	192.9	173.61	1$\frac{1}{5}$ in.	.057 in.
Quarter-dollar,	96.45	86.805	$\frac{19}{20}$ "	.045 "
Dime,	38.58	34.725	$\frac{7}{10}$ "	.032 "

Fineness of all 900-thousandths.

The half-dollar now weighs exactly 12½ grammes, two being equal to the five-franc piece of France, in weight and fineness.

The present **minor coins** are:

Five-cent nickel of 77.16 grains, 75 per cent. copper, 25 per cent. nickel, specific gravity 8.940, 93 weighing a pound Avoirdupois.

One-cent. bronze, of 48 grains, 95 per cent. copper, 5 per cent. tin and zinc, specific gravity 8.782, 145 weighing a pound Avoirdupois.

Legal tender to the amount of twenty-five cents, redeemable at any sub-treasury in sums of \$20.00 or more, furnished free of transportation charge from the mint at Philadelphia, and obtainable in exchange at any sub-treasury.

The dimensions are: Five-cent pieces: diameter, $\frac{4}{5}$ths of an inch; thickness, .062 of an inch. One-cent piece: diameter, ¾ of an inch; thickness, .043 of an inch.

MINOR COINAGE, 1793-1894.

DENOMINATION.	PERIOD	AMOUNT.
Half-cents,	1793-1857,	\$ 39,926.11
Copper cents,	1793-1857,	1,562,887.44
Copper-nickel cents,	1857-1864,	2,007,720.00
Bronze cents,	1864-1894,	7,463,898.26
Two-cent pieces,	1864-1873,	912,020.00
Three-cent nickels,	1865-1889,	941,349.48
Five-cent nickels,	1866-1894,	13,663,730.50
Total,		\$26,481,531.79

Digitized by Google

TABLE OF COMPARATIVE VALUES PER POUND AND PER KILOGRAMME.

Reckoning the French Franc at $19\frac{30}{100}$ cents, the German Mark at $23\frac{81}{100}$ cents, and the English Shilling at $24\frac{1}{3}$ cents, and the Kilogramme as equivalent to 2.20462 pounds Avoirdupois.

Cents Per Lb.	Shillings Per Lb.			Francs per Kilo. .193	Marks per Kilo. .2381	Cents Per Lb.	Shillings Per Lb.			Francs per Kilo. .193	Marks per Kilo. .2381
	s.	d.	Farthings.				s.	d.	Farthings.		
1	0	0.	1.9726	.114229	.092592	24	0	11.	3.3424	2.741496	2.222210
2	0	0.	3.9452	.228458	.185184	25	1	0.	1.3150	2.855725	2.314802
3	0	1.	1.9178	.342687	.277776	26	1	0.	3.2876	2.969954	2.407394
4	0	1.	3.8904	.456916	.370368	27	1	1.	1.2602	3.084183	2.499986
5	0	2.	1.8630	.571145	.462960	28	1	1.	3.2328	3.198412	2.592578
6	0	2.	3.8356	.685374	.555552	29	1	2.	1.2054	3.312641	2.685170
7	0	3.	1.8082	.799603	.648144	30	1	2.	3.1780	3.426870	2.777763
8	0	3.	3.7808	.913832	.740736	31	1	3.	1.1506	3.541099	2.870355
9	0	4.	1.7534	1.028061	.833328	32	1	3.	3.1232	3.655328	2.962947
10	0	4.	3.7260	1.142290	.925921	33	1	4.	1.0958	3.769557	3.055539
11	0	5.	1.6986	1.256519	1.018513	34	1	4.	3.0684	3.883786	3.148131
12	0	5.	3.6712	1.370748	1.111105	35	1	5.	1.0410	3.998015	3.240723
13	0	6.	1.6438	1.484977	1.203697	36	1	5.	3.0136	4.112244	3.333315
14	0	6.	3.6164	1.599206	1.296289	37	1	6.	0.9862	4.226473	3.425907
15	0	7.	1.5890	1.713435	1.388881	38	1	6.	2.9588	4.340702	3.518499
16	0	7.	3.5616	1.827664	1.481473	39	1	7.	0.9314	4.454931	3.611091
17	0	8.	1.5342	1.941893	1.574065	40	1	7.	2.9040	4.569160	3.703684
18	0	8.	3.5068	2.056122	1.666657	41	1	8.	0.8766	4.683389	3.796276
19	0	9.	1.4794	2.170351	1.759249	42	1	8.	2.8492	4.797618	3.888868
20	0	9.	3.4520	2.284580	1.851842	43	1	9.	0.8218	4.911847	3.981460
21	0	10.	1.4246	2.398809	1.944434	44	1	9.	2.7944	5.026076	4.074052
22	0	10.	3.3972	2.513038	2.037026	45	1	10.	0.7670	5.140305	4.166644
23	0	11.	1.3698	2.627267	2.129618	46	1	10.	2.7396	5.254534	4.259236

Digitized by Google

TABLE OF COMPARATIVE VALUES PER POUND AND PER KILOGRAMME.—Continued.

Cents Per Lb.	Shillings Per Lb. s.	d.	Farthings.	Francs per Kilo. .193	Marks per Kilo. .2381	Cents per Lb.	Shillings Per Lb. s.	d.	Farthings.	Francs pe Kilo. .193	Marks per Kilo. .2381
47	1	11.	0.7122	5.368763	4.351828	74	3	0.	1.9726	8.452946	6.851815
48	1	11.	2.6848	5.482992	4.444420	75	3	0.	3.9452	8.567175	6.944407
49	2	0.	0.6574	5.597221	4.537012	76	3	1.	1.9178	8.681404	7.036999
50	2	0.	2.6310	5.711450	4.629605	77	3	1.	3.8904	8.795633	7.129591
51	2	1.	0.6026	5.825679	4.722197	78	3	2.	1.8630	8.909862	7.222183
52	2	1.	2.5752	5.939908	4.814789	79	3	2.	3.8356	9.024091	7.314775
53	2	2.	0.5478	6.054137	4.907381	80	3	3.	1.8082	9.138320	7.407368
54	2	2.	2.5204	6.168366	4.999973	81	3	3.	3.7808	9.252549	7.499960
55	2	3.	0.4930	6.282595	5.092565	82	3	4.	1.7534	9.366778	7.592552
56	2	3.	2.4656	6.396824	5.185157	83	3	4.	3.7260	9.481007	7.685144
57	2	4.	0.4382	6.511053	5.277749	84	3	5.	1.6986	9.595236	7.777736
58	2	4.	2.4108	6.625282	5.370341	85	3	5.	3.6712	9.709465	7.870328
59	2	5.	0.3834	6.739511	5.462933	86	3	6.	1.6438	9.823694	7.962920
60	2	5.	2.3560	6.853740	5.555526	87	3	6.	3.6164	9.937923	8.055512
61	2	6.	0.3286	6.967969	5.648118	88	3	7.	1.5890	10.052152	8.148104
62	2	6.	2.3012	7.082198	5.740710	89	3	7.	3.5616	10.166381	8.240696
63	2	7.	0.2738	7.196427	5.833302	90	3	8.	1.5342	10.280610	8.333289
64	2	7.	2.2464	7.310656	5.925894	91	3	8.	3.5068	10.394839	8.425881
65	2	8.	0.2190	7.424885	6.018486	92	3	9.	1.4794	10.509068	8.518473
66	2	8.	2.1916	7.539114	6.111078	93	3	9.	3.4520	10.623297	8.611065
67	2	9.	0.1642	7.653343	6.203670	94	3	10.	1.4246	10.737526	8.703657
68	2	9.	2.1368	7.767572	6.296262	95	3	10.	3.3972	10.851756	8.796249
69	2	10.	0.1094	7.881801	6.388854	96	3	11.	1.3698	10.965985	8.888841
70	2	10.	2.0821	7.996030	6.481447	97	3	11.	3.3424	11.080214	8.981433
71	2	11.	0.0547	8.110259	6.574039	98	4	0.	1.3150	11.194443	9.074025
72	2	11.	2.0274	8.224488	6.666631	99	4	0.	3.2876	11.308672	9.166617
73	3	0.	0.0000	8.338717	6.759223	100	4	1.	1.2602	11.422901	9.259210

Digitized by Google

TABLE ILLUSTRATING THE MONETARY SYSTEM OF THE UNITED STATES.—MAY 1896.

AUTHORITY.—MONETARY SYSTEM OF THE WORLD BY M. L. MUHLEMAN.

	Gold Coin.	Gold Certificates.	Silver Dollars.	Silver Certificates.	United States Notes.	Currency Certificates.	Treasury Notes of 1890.	National Bank Notes.	Subsidiary Silver Coin.	Minor Coin.
Weight, ...	25.8 grains to the dollar.	—	412.5 grains.	—	—	—	—	—	385.8 gr. to the dollar.	5c. piece. 77.16 grains. 75 p.c. cop'r. 25 p.c. nick'l 1c. piece. 48 grains. 95 p.c. cop'r. 5 per ct. tin and zinc.
Fineness, . . .	900-1000	—	900–1000	—	—	—	—	—	900-1000	
Ratio to Gold,	. . . .	—	15.988 to 1.	—	—	—	—	—	14.953 to 1	
Limit of Issue,	Unlimited; coinage free.	Issue suspended so long as free gold in Treasury is below $100-000,000.	Requirement to redeem Treasury Notes.	Silver dollars in use.	$346,681,016	The same as United States Notes.	Silver bullion and dollars of 1890 in Treasury.	Volume of United States bonds and their cost.	Needs of the country.	Needs of the country,
Denominations	$20 10 5 2 1-2	$10,000 5,000 1,000 500 100 50 20	$1	$1000 500 100 50 20 10 5 2 1	$1,000 500 100 50 20 10 5 2 1	$10,000	$1,000 100 50 20 10 5 2 1	$1,000 500 100 50 20 10 5	50 cents. 25 cents. 10 cents.	5 cents. 1 cent.
Legal Tender,.	Unlimited.	Not a tender.	Unlimited unless otherwise contracted.	Not a tender.	Unlimited unless otherwise contracted.	Not a tender.	Unlimited unless otherwise contracted.	Not a tender.	Not to exceed $10.	Not to exceed 25 cents.
Receivable, . .	For all dues.	For all public dues.	For all dues.	For all public dues.	For all dues.*	Not receivable.	For all dues.	For all dues except duties on imports and interest on public debt.	To the amount of $10 for all. dues.	To the amount of 25 cents for all dues.
Exchangeable,	For certificates under the limitation.	For gold coin at the Treasury, or any other moneys.	For silver certificates or smaller coin at the Treasury.	For dollars or smaller coin at the Treasury.	For all kinds of moneys except gold certificates.	For United States notes.	For all kinds of moneys except gold certificates.	For silver and minor coin.	For minor coin.	—
Redeemable,. .	—	In gold coin at the Treasury.	And may be deposited for silver certificates.	In silver dollars.	In coin at sub-treasury in New York and San Francisco in sums of $50 and over.	In United States notes at sub-treasury where issued.	In coin at the Treasury or any Sub-Treasury	In "lawful money" at the treasury or bank of issue.	In "lawful money" at the treasury in sums of $20 or any multiple.	In "lawful money" at the Treasury in sums of $20 or more.

*Duties on imports by regulation only.

FINENESS OF COINS.

U. S. Silver Dollar weighs	$412\frac{1}{2}$	grains Troy,		$\frac{9}{10}$ pure silver.	
U. S. Gold " "	$25\frac{8}{10}$	"	"	$\frac{9}{10}$ pure gold.	

The pure gold in a U. S. Gold Dollar weighs 23.21997 grains Troy.

The English "Unit" is the "Sovereign" or pound sterling, weighing 113.0016 grains Troy, of pure gold. The ratio of the gold of one U. S. Dollar to the gold in one Sovereign is as 1 is to 4.866.

The Unit of value in Germany is the grains of gold in a Mark, namely 5.53134 grains.

The Unit of value in France is the grains of gold in a Franc, namely 4.48035 grains.

$5 gold coin of U. S.,	contains	116.09985	grains	of pure	gold.
£ 1 Eng. Sovereign, (20 shillings,)....	"	113.00160	"	"	"
The German 20 mark piece	"	110.62680	"	"	"
The French 20 franc piece	"	89.607	"	"	"
The Spanish 25 pesetas p'ce	"	112.0060	"	"	"

U. S. VALUES OF MARKS AND FRANCS.

1 Mark = 23.81 cents.	x 2, =	47.62	cents.
"	x 3, =	71.43	"
"	x 4, =	95.24	"
"	x 5, =	119.05	"
"	x 6, =	142.86	"
"	x 7, =	166.67	"
"	x 8, =	190.48	"
"	x 9, =	214.29	"
1 Franc = 19.3	x 2, =	38.6	"
"	x 3, =	57.9	"
"	x 4, =	77.2	"
"	x 5, =	96.5	"
"	x 6, =	115.8	"
"	x 7, =	135.1	"
"	x 8, =	154.4	"
"	x 9, =	173.7	"

Digitized by Google

CUSTOM DUTIES ON ALUMINUM IN VARIOUS COUNTRIES, IN MAY, 1896.

UNITED STATES.

Custom Laws of 1894: Aluminum in crude form; alloys of any kind in which aluminum is the component material of chief value, ten cents per lb.

Manufactured articles or wares, composed wholly or in part of aluminum, and whether partly or wholly manufactured, thirty-five per centum, ad valorem.

FRANCE.

General Customs Tariff, approved January 11th, 1892.

SECTION 203. Aluminum, General Tariff, 200 francs per 100 kilograms; Minimum Tariff, 150 francs per 100 kilograms.

SECTION 205. Ferro aluminum, containing 10 per cent. of aluminum or less, General Tariff, 4.75 francs per 100 kilograms; Minimum Tariff, 3.50 francs per 100 kilograms.

Ferro-aluminum, containing more than 10 per cent. of aluminum and less than 20 per cent. of aluminum, General Tariff, 9.00 francs per 100 kilograms; Minimum Tariff, 7.50 francs per 100 kilograms.

SECTION 221. Aluminum bronze, crude, containing more than 20 per cent. of aluminum, General Tariff, 13 francs per 100 kilograms; Minimum Tariff, 13 francs per 100 kilograms.

SECTION 496. Imitation jewelry of aluminum, General Tariff, 250 francs per 100 kilograms; Minimum Tariff, 200 francs per 100 kilograms.

All additional taxes on importations of aluminum are included in the above rates.

The word "general" used in the French law, covers the tariff duty applicable to all States or Countries generally, i. e., those states or countries that have not entered into a special arrangement or treaty—in the form of a reciprocity treaty—with France.

Digitized by Google

The word "minimum" applies to the duty to be assessed on articles imported from countries that have entered into a special treaty with France. It is the lowest duty.

The following states are entitled to the minimum tariff, in virtue of treaties, conventions or laws made between them and France:

Argentine Republic, Austria Hungary, Belgium, Bolivia, Bulgaria, Columbia, Denmark, Dominican Republic, Germany, Great Britain, Greece, Luxembourg, (Grand Duchy), Madagascar, Morocco, Montenegro, Netherlands, Ottoman Empire, Paraguay, Persia, Roumania, Russia, Servia, South African Republic, Spain, Sweden and Norway, Switzerland, UNITED STATES, Uruguay.

GERMANY.

Law of July 15th, 1879. Ingots and unworked aluminum metal, duty free.

SECTION 19 (*b*). Aluminum, rolled, 9 marks per 100 kilos.

SECTION 19 (*d-e*). Aluminum wares, 60 marks per 100 kilos.

Law of May 18th, 1895.

SECTION 20 (*b-2*), Fine, fancy and small wares composed wholly or in part of aluminum, 200 marks per 100 kilos; conventional duty, 175 marks per 100 kilos.

The conventional duties of Germany are applicable to goods proceeding from treaty countries, and by virtue of a decision of the Bundesrath in 1892, the following countries are declared to be treaty countries:

Argentine Republic, Chile, Belgium, Costa Rica, Denmark, Dominican Republic, Ecuador, France, Greece, Great Britain, Guatemala, Hawaii, Honduras, Italy, Corea, Liberia, Madagascar, Morocco, Mexico, Netherlands, Austria Hungary, Paraguay, Persia, Salvador, Sweden and Norway, Switzerland, Servia, South African Republic, Turkey, UNITED STATES, Zanzibar.

Digitized by Google

HOLLAND.

Tariff of August, 1862, as last modified.

ARTICLE 2. Aluminum is admitted free.

ARTICLE 52. Manufactures of aluminum, 5 per cent. ad valorem.

BELGIUM.

ARTICLE 37. Aluminum when unworked, free.

ARTICLE 33. Articles of aluminum, 10 per cent. ad valorem.

Decision of May 30th, 1891. Ferro aluminum, 50 centimes per 100 kilos.

Digitized by Google

INDEX.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

CHEM

Digitized by Google

CHEM. BLDG. U. C. LIBRARY

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

THIS BOOK IS DUE ON THE LAST DATE
STAMPED BELOW

AN INITIAL FINE OF 25 CENTS

WILL BE ASSESSED FOR FAILURE TO RETURN THIS BOOK ON THE DATE DUE. THE PENALTY WILL INCREASE TO 50 CENTS ON THE FOURTH DAY AND TO $1.00 ON THE SEVENTH DAY OVERDUE.

FEB 22 1937

JAN 25 1938

18Mar'49

D 15Jun'50GE

LIBRARY USE

JUN 23 1956

LIBRARY USE

APR 29 1961

REC'D LD

APR 29 1961

LIBRARY USE

MAY 6 '66

MAY 6 '66 3 R CD

[redacted]

LD 21-100m

Digitized by Google